

ANNUAL REPORT

of the

WEST AFRICAN
COCOA RESEARCH
INSTITUTE

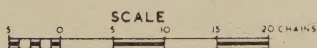
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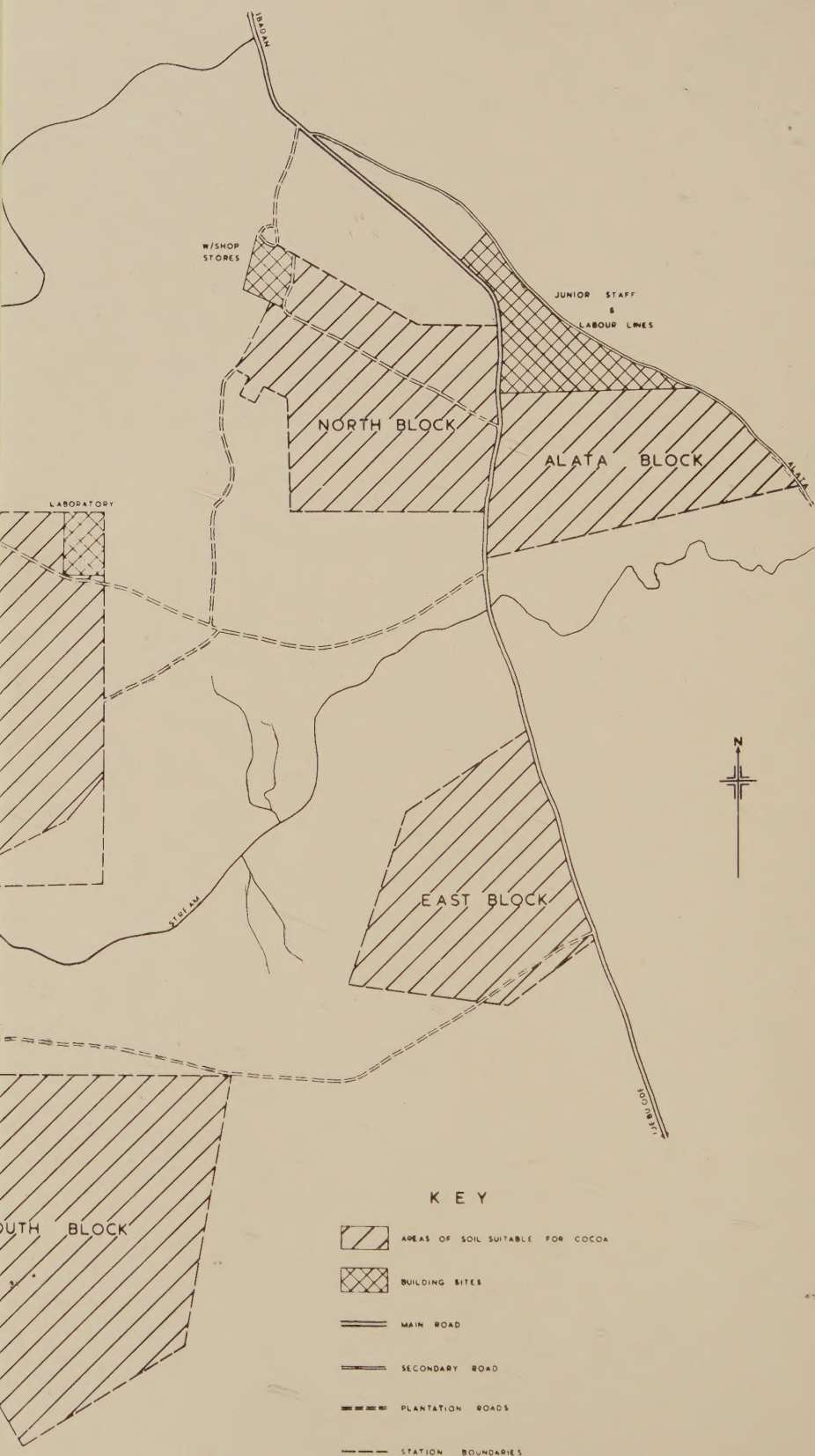
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GAMBARI EXPERIMENTAL STATION





ANNUAL REPORT
of the
WEST AFRICAN
COCOA RESEARCH
INSTITUTE

1961-62

Price 5/-

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West African Cocoa Research Institute
1963

**A POISONOUS INSECTICIDAL SOLUTION
HAS BEEN USED IN BINDING THIS BOOK**

CONTENTS

	<i>Page</i>
MANAGING COMMITTEE	6
SENIOR STAFF	7

ADMINISTRATION

MANAGING COMMITTEE	9
STAFF	9
CONFERENCES AND VISITS	10
VISITORS	10
TAFO STATION AND PLANTATION MANAGEMENT	11
<i>Weather summaries</i>	12
<i>Cocoa production</i>	13
GAMBARI EXPERIMENTAL STATION, IBADAN	13

RESEARCH

TAFO STATION

VIRUS RESEARCH	16
<i>Mechanical transmission of cocoa viruses</i>	16
<i>Effects of virus on growth and yield</i>	17
<i>Resistance and tolerance</i>	19
BLACK-POD DISEASE	21
<i>Resistance and tolerance</i>	21
<i>Root infection of cocoa by Phytophthora palmivora Butl.</i>	25
MEALYBUG STUDIES	28
<i>Joint W.A.C.R.I./Division of Agriculture ant/mealybug control trials</i>	28
CAPSID STUDIES	30
POLLINATION STUDIES	31
MINOR PESTS	31
NEMATODE STUDIES	32

	Page
ESTABLISHMENT AND MAINTENANCE EXPERIMENTS	33
<i>Spacing experiments</i>	33
<i>Pruning experiments</i>	36
<i>Shade efficiency experiment</i>	37
<i>Management study of clonal cocoa</i>	38
<i>Experiments planted 1960</i>	38
<i>New experiments</i>	39
<i>Regeneration of Old Station</i>	39
<i>Vegetative propagation</i>	40
<i>Nursery trials</i>	43
<i>Black-pod resistance trial</i>	44
PLANT BREEDING AND SELECTION	44
<i>Flavour of cocoa varieties</i>	46
<i>Small field experiments</i>	47
<i>Nursery experiment</i>	48
<i>Studies on crop setting in a large block of a self-incompatible clone</i>	50
<i>Studies on the first clonal trial</i>	50
<i>Commencement of a new cycle of plant breeding</i>	52
<i>Report on the varieties: check list: explanatory notes</i>	53
<i>Performance of Amelonado cocoa from several sources</i>	53
PHYSIOLOGY OF COCOA.. ..	54
<i>The greenhouse</i>	54
<i>Techniques of sand and nutrient preparation</i>	55
<i>Composition of complete nutrient solutions</i>	56
<i>Effects of macronutrients and virus on the growth of cocoa seedlings</i>	57
<i>Leaf edge scorch</i>	60
<i>Effects of micronutrients and cocoa swollen shoot virus</i>	61
<i>Copper spray trial</i>	64
<i>Comparison of growth of half bean and full bean seedlings</i>	64
<i>Comparison of growth of cocoa seedlings infected with different virus isolates</i>	66
SOIL FERTILITY, COVER CROPS, IRRIGATION AND SHADE ..	67
<i>Effects of major nutrients</i>	67
<i>Cover crops and mulches</i>	72
<i>Soil chemistry</i>	73
<i>Shade and fertilizer experiment - foliar analysis</i>	78
<i>Spectrographic analysis of forest zone soils</i>	79

	<i>Page</i>
COCOA PREPARATION AND QUALITY	79
<i>Assessment results</i>	79
<i>Mechanical drying</i>	80
STATISTICS	81

IBADAN STATION

VIRUS RESEARCH	81
<i>Mechanical transmission</i>	81
<i>Virus tolerance</i>	82
BLACK-POD STUDIES	87
<i>Strains of Phytophthora Palmivora Butl.</i>	87
<i>Black-pod control trials</i>	90
ENTOMOLOGY	100
<i>Shot-hole borers</i>	100
<i>Earias biplaga</i>	103
<i>Minor pests</i>	109
NEMATOLOGY STUDIES	113
PLANT BREEDING	114
<i>History of cocoa breeding in Nigeria</i>	114
<i>Introductions</i>	116
<i>Incompatibility and marker genes</i>	117
SOIL CHEMISTRY	118
<i>Fertilizer trials</i>	118
<i>Zinc deficiency</i>	119
AGRONOMY	121
<i>Spacing trial</i>	121
<i>Nursery trial</i>	123
<i>Shade observation trial</i>	126
STATISTICS	128
PUBLICATIONS	129

MANAGING COMMITTEE

At 31st March 1962

CHAIRMAN

- *†Administrator, West African Research Office.

MEMBERS

- *†Chairman, Ghana Agricultural Produce Marketing Board.
- *†Executive Secretary, National Research Council of Ghana.
- *†‡Chief Cocoa Officer, Ghana.
Imoru Egala, Esq., Ghana.
S. E. Ntim-Kwafo, Esq., Ghana.
- †Permanent Secretary, Federal Ministry of Economic Development, Nigeria.
- ‡Director of Agricultural Research, Federation of Nigeria.
- †Permanent Secretary, Ministry of Agriculture and Natural Resources, Western Region, Nigeria.
- ‡Controller of Agricultural Services, Ministry of Agriculture and Natural Resources, Western Region, Nigeria.
Rev. E. T. Latunde, O.B.E., Nigeria.
- †‡Director of Agriculture, Sierra Leone.
- *†‡Director, West African Cocoa Research Institute.

Co-OPTED MEMBERS (non-voting)

- W. R. Feaver, Esq., C.B.E., P.O. Box 49, Accra, Ghana.
Manager, Messrs Rowntree-Fry-Cadbury, Nigeria.
- ‡Chief Inspector of Agriculture, Department of Agriculture, Enugu, Eastern Nigeria.
- *†‡Deputy Director (Nigeria), West African Cocoa Research Institute, Ibadan, Nigeria.
Secretary, West African Cocoa Research Institute, Ghana.

* Member of General Purposes Sub-Committee

† Member of Staff Sub-Committee

‡ Member of Technical Sub-Committee

SENIOR STAFF

At 31st March 1962

TAF0 STATION

ACTING DIRECTOR	..	J. W. Blencowe, PH.D.
SECRETARY	..	A. F. Neale, M.A., F.C.C.S.
ASST. SECRETARY	..	G. E. T. Adediran, A.C.C.S., A.COMM.A., F.R.ECON.S.
ACCOUNTANT	..	J. N. A. Hyde, A.C.C.S., A.A.I.A.
ASST. ACCOUNTANT	..	E. N. O. Dodoo
LIBRARIAN	..	T. W. Cochran, A.L.A.
ENTOMOLOGISTS	..	*J. A. Dunn, M.SC., PH.D. R. G. Donald, B.SC., A.I.C.T.A., M.I.BIOL., F.R.E.S. B. M. Gerard, PH.D., A.R.C.S., F.R.E.S.
PLANT PATHOLOGISTS	..	A. L. Wharton, B.SC., DIP.AG.SCI., D.T.A., M.I.BIOL. A. A. F. Brunt, B.SC., M.I.BIOL.
PLANT PHYSIOLOGISTS	..	†R. G. Lockard, B.S.A., M.SC., PH.D. E. J. A. Asomaning, B.SC., M.SC., PH.D.
PLANT BREEDERS	..	D. R. Glendinning, B.SC. Miss V. A. Martinson, B.SC.
CHEMISTS	..	‡R. H. Kenten, B.SC., A.R.I.C. D. K. Acquaye, B.SC., PH.D.
SPECTROGRAPHER	..	J. C. Burrige, M.A., B.SC.
AGRONOMISTS	..	T. H. R. Hall, B.SC. R. W. Smith, B.SC.
STATISTICIAN	..	C. de Jonge, L.I., A.R.N.S.A.S.
ASST. SPECIALIST	..	A. Attafuah, M.I.BIOL.
ASST. EXPERIMENTAL OFFICERS	..	E. O. Boafo N. K. Lovi E. A. T. Asante J. K. Bonney G. S. Akrofi

* Seconded from National Vegetable Research Station, Wellesbourne, Warwick, England

† On Canadian Technical Assistant Scheme

‡ Seconded from Rothamsted Experimental Station, Harpenden, Herts, England

MEDICAL OFFICER	..	P. K. K. Knudsen, CAND. MED. ET. CHIR., D.T.M. & H.
PLANTATION MANAGER	..	H. W. S. Allison
ASST. PLANTATION MANAGER		E. O. Quao
GUIDE-DEMONSTRATOR	..	F. E. Decker
MAINTENANCE AND ELECTRONICS ENGINEER		G. O. Hayward, A.I.E.E.
ASST. MAINTENANCE ENGINEER		G. O. Amponsah
WORKS SUPERINTENDENT	..	E. K. Berko

IBADAN STATION

DEPUTY DIRECTOR	..	T. W. Tinsley, B.SC., PH.D., M.I.BIOL.
SECRETARY		H. Ll. Pugh, F.C.C.S.
ENTOMOLOGIST		P. F. Entwistle, B.SC., A.R.C.S., F.R.E.S.
PLANT PATHOLOGISTS	..	C. K. H. Martini, PH.D. E. C. Hislop, B.SC., D.P.P. J. F. Longworth, M.SC., M.I.BIOL. G. Weststeijn, L.I. P. C. Wessel-Riemens (Mrs.), L.I.
CHEMIST		M. Wessel, L.I.
PLANT BREEDER		H. Toxopeus, L.I.
AGRONOMISTS		G. H. Freeman, M.A., DIP.STAT., PH.D. J. T. Swarbrick, B.SC., S.A.T., DIP.AG., M.I.BIOL.
PLANT PHYSIOLOGIST	..	N. I. C. Nwachuku, B.SC.
PLANTATION OFFICER	..	W. Rides
ASST. PLANTATION OFFICER		V. O. Iweama

ADMINISTRATION

MANAGING COMMITTEE

The 32nd Meeting of the Managing Committee was held on 2nd and 3rd March, 1962 at Ibadan.

STAFF

The following officers were on leave during the periods stated against their names:

- Mr T. H. R. Hall (from 1st to 23rd April 1961).
- Mr A. F. Neale (from 1st April to 23rd July 1961).
- Mr C. de Jonge (from 1st April to 24th July 1961).
- Mr R. W. Smith (from 26th April to 19th August 1961).
- Mr J. C. BurrIDGE (from 19th May to 7th November 1961).
- Dr P. K. K. Knudsen (from 1st June to 17th August 1961).
- Mr H. W. S. Allison (from 27th July to 27th December 1961).
- Dr R. G. Lockard (from 21st November, 1961 to 8th March 1962).
- Mr H. Ll. Pugh (from 26th June to 13th September 1961).
- Mr R. G. Donald (from 16th August to 19th December 1961).
- Mr P. F. Entwistle (from 18th May to 1st September 1961).
- Mr J. F. Longworth (from 16th April to 2nd August 1961).
- Mr E. C. Hislop (from 16th February to 19th July 1961).

Acting Appointments

- Dr J. W. Blencowe acted as Director throughout the year under review.
- Mr P. F. Entwistle took over as Acting Deputy Director (Nigeria), on 22nd March 1962.
- Mr J. N. A. Hyde acted as Secretary in the absence of Mr. A. F. Neale on leave, in addition to his duties as Accountant.

New Arrivals

- Dr J. A. Dunn, August 1961.
- Miss V. A. Martinson, September 1961.
- Mr G. E. T. Adediran, December 1961.
- Mr E. N. O. Dodoo, December 1961.
- Mr T. W. Cochrane, January 1962.
- Mr N. I. C. Nwachuku, April 1961.
- Mr J. T. Swarbrick, March 1962.
- Mr H. Toxopeus, June 1961.
- Mr. G. Weststeijn, October 1961.
- Mrs P. C. Wessel-Riemens (part-time), May 1961.

Transfers

- Mr R. G. Donald transferred from Ibadan to Tafo with effect from 12th January 1962.

Promotions

The following Senior Technical Assistants were promoted to the grade of Assistant Experimental Officer with effect from 1st April 1961:

E. O. Boafo

N. K. Lovi

E. A. T. Asante

J. K. Bonney

G. S. Akrofi

Mr V. O. Iweama entered the Senior Staff grade as Assistant Plantation Officer at Ibadan on 15th December 1961.

Resignations

Mr K. B. Armstrong went on final leave on 14th September 1961.

Mr E. Dunn went on final leave on 23rd September 1961.

Dr M. R. Smith went on final leave on 18th October 1961.

Mr P. D. Turner went on final leave on 30th December 1961.

Dr C. K. H. Martini went on final leave on 21st June 1961.

Dr T. W. Tinsley went on final leave on 22nd March 1962.

CONFERENCES AND VISITS BY STAFF

Dr J. W. Blencowe attended an F.A.O. Conference in Rome in July 1961 on problems of plant exploration, introduction and quarantine.

Dr Blencowe, Dr T. W. Tinsley, Mr R. G. Donald and Mr H. W. S. Allison attended the London Cocoa Conference in September 1961.

Dr E. J. A. Asomaning attended a conference in Vienna in December 1961, on the application of isotopes and radiation to agricultural research in tropical Africa, sponsored by the International Atomic Energy Agency.

In May 1961 Mr P. F. Entwistle spent ten days working in the Musée Nationale d'Histoire Naturelle, Paris.

Messrs E. C. Hislop and H. Toxopeus visited Fernando Po in March 1962 to study black pod and to investigate breeding material and agronomic practice respectively.

VISITORS

Tafo station was honoured by a visit from Mr A. Mikoyan, Deputy Prime Minister of the Soviet Union in February 1962. Both stations were visited by the Duke of Devonshire, Under Secretary of State for Commonwealth Relations, and Tafo station was visited by Sir Geoffrey de Freitas, K.M.C.G., British High Commissioner in Ghana

and Lady de Freitas. Both stations were visited by Ambassadors, Ministers and persons distinguished in the fields of science, commerce and industry.

TAFO STATION AND PLANTATION MANAGEMENT

New Plantings

Planting of the 40 acres clear-felled in 1960/61, comprising 24 acres of Amazon and Hybrid seedlings in Block A, 10 acres of Amazon seed at stake in Block C and 6 acres of Amazon and Hybrid seedlings in Block D, was completed. Amelonado and Amazon seedlings were also planted on 0.75 acres in Block E for Pathology Division.

78 acres in the Square Mile were clear-felled for planting in 1962 and 1963, comprising 3 acres in Block A, 8 acres in Block D, 6 acres in Block E, 40 acres in Block F, 4 acres in Block H, 10 acres in Block J and 7 acres in Block M.

Forest tree and ornamental nursery

Eureka lemon, Anamabu sweet orange and Marsh seedless grapefruit budded on sour and sweet orange rootstocks were raised for the residential area, as well as various ornamental shrubs. Seedlings of *Terminalia invorensis* A. Chev. were planted for shade for new plantings. An extension of the nursery was made to raise pawpaw seedlings required for an establishment trial in 1962.

Seed and cutting production

During the main crop season 36,000 pods and 3,500 pods of F3 Upper Amazon were sent to the Western and Northern Regions of Nigeria respectively, and 3,000 pods were despatched to Sierra Leone. 33,000 F3 Amazon pods from light crop harvestings and from main crop pods unfit for export, and 2,200 Amelonado pods were sold to members of the W.A.C.R.I. staff.

9,700 cuttings of various clones were set during the year, 85 per cent of them rooting successfully.

During the year the clonal nursery was extended to include twenty rooted cuttings each of thirty-four clones.

Building construction, etc.

Considerable progress has been made with the construction of new latrines, sewers and an Imhoff Tank sewage disposal system to replace the inadequate septic tank latrines in the laboratory and works area.

Three new blocks of two quarters each were completed in the W.A.C.R.I. Village and occupied by junior staff. Repairs and

TABLE I

Meteorological data — Tafo 1961. Figures for 1961 compared with 24-year means

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum 24-year mean	91.7	94.0	93.3	93.8	92.3	89.1	86.9	86.8	87.9	89.7	90.6	90.6
1961	96	96	95	95	94	91	85	87	87	89	90	90
Lowest Shade Minimum 24-year mean	59.5	62.1	66.3	66.8	67.2	66.5	65.8	65.3	67.1	67.0	66.0	62.4
1961	61	65	68	65	68	68	67	66	66	68	67	58
Mean Relative Humidity 24-year mean	86.2	83.7	82.0	80.9	81.9	85.0	86.1	85.8	85.2	83.3	81.3	84.2
(0900 G.M.T.)	82.8	79.3	80.7	77.3	79.9	84.6	88.4	83.2	84.2	82.2	81.3	85.8
Mean Relative Humidity 24-year mean	56.3	53.5	57.5	62.8	67.7	74.1	74.1	72.3	71.3	70.9	66.1	62.0
(1500 G.M.T.)	60.4	50.7	60.0	63.4	64.3	77.7	78.0	67.4	71.9	69.2	68.1	65.7
Rainfall in inches 24-year mean	1.49	3.44	5.96	6.14	7.25	9.22	5.63	2.43	6.09	8.73	4.22	2.55
1961	0.09	1.89	2.74	2.95	3.83	16.46	6.78	0.58	5.85	5.89	3.95	1.67
Number of Wet Days 24-year mean	3.7	6.8	12.0	10.9	13.7	19.1	14.1	12.3	16.8	18.8	11.2	6.4
1961	3	2	11	10	9	23	20	6	11	19	11	7

Annual rainfall (in inches) 1938 to 1961

	1938-47	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	24-year Mean
Mean	61.47	66.99	71.81	63.49	66.23	65.77	53.88	57.53	73.16	51.12	70.90	61.86	68.13	77.27	52.68	63.15

Monthly rainfall (in inches) and number of wet days, April 1961 to March 1962

Month	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
Rainfall in inches	2.95	3.83	16.46	6.78	0.58	5.85	5.89	3.95	1.67	1.30	1.59	6.79
Number of Wet Days	10	9	23	20	6	11	19	11	7	2	6	14

improvements to other junior staff houses and resealing of tarred roads were commenced in October 1961 under an agreement with the Division of Public Construction.

Work commenced during the latter part of the year on the erection of new carpentry and motor workshops. Most of the machinery which is to be installed to improve the efficiency of maintenance work has been delivered to Tafo and is awaiting completion of the building.

A contract was awarded for the construction of six new senior staff bungalows which are due to be ready for occupation in November 1962.

Cocoa production

A total weight of 175,938 lb. of dry cocoa was produced during the year; 164,080 lb. were sold for £G7,622. Recorded data from 299 tray, 309 heap and 16 sweat box fermentations were obtained. 37.5 tons of cocoa were dried in the Mechanical Dryer. An abnormal proportion of ripe pods containing immature beans were harvested during the year. Out of the 2,675,000 pods received, 12.3 per cent were discarded because the beans were unfit for fermentation. The average conversion factor of fresh wet beans to fermented sun-dried beans was 44.5 per cent by weight; on average 12.8 pods yielded 1 lb. of dry cocoa.

Plots Committee

The Plots Committee met at regular intervals throughout the year to consider the utilisation of land and planting material for the 1962 plantings. The use of the Old Station to demonstrate methods of regenerating old cocoa whose yield was on the decline was recommended to the Technical Sub-Committee. Membership of the Committee was increased by one to provide for representation of more scientific disciplines.

GAMBARI EXPERIMENTAL STATION, IBADAN

Acquisition

A survey of the Station boundaries is being conducted by the Survey Department, Ministry of Lands and Housing, Western Region. On conclusion of this survey it is thought that the lease for land upon which the Station stands may be finally approved.

Buildings

Progress on the building programme is well up to schedule and further clearing of sites to accommodate 1962-63 buildings is in hand.

TABLE 2
Meteorological data – Gambari Experimental Station 1961

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean Shade Maximum	89	83	95	89	90	86	82	81	84	88	91	92
Mean Shade Minimum	64	68	72	71	72	71	71	68	70	70	71	68
Mean Relative Humidity (0900 G.M.T.)	87	81	77	83	83	87	89	86	86	84	84	83
Mean Relative Humidity (1500 G.M.T.)	64	53	50	68	69	81	87	79	74	72	70	65
Rainfall (in inches)	0.24	Nil	2.69	7.49	4.75	12.15	3.30	1.03	7.05	7.29	0.10	Nil
Wet days	1	Nil	5	12	11	19	23	4	16	16	2	Nil

Total rainfall 46.09 inches on 109 wet days

Domestic water supply

The installation of the filter plant and supply system for domestic water is nearly completed. A delay has been occasioned by the non-arrival of raw water pumps but these are now in transit. The Ibadan Water Works Division are prepared to render the necessary assistance for the erection of plant and laying of supply pipe lines. Facilities for the training of a Filter Plant Operator have also been made available and one man is at present undergoing a course.

Electricity

Delivery of equipment and materials for the Station electricity supply has commenced. Trenching for cable laying is well in hand, the purchase of a Dinkum Digger fitted to and powered by the Fordson Power Major tractor having proved a great asset.

Fire precautions

In consultation with the Ibadan Fire Service adequate equipment has been purchased to cover fire risks. Members of the staff will receive instruction in the use of the fire fighting equipment through the Ibadan Fire Service, who have been most co-operative.

Transport

On completion of the workshop and garage buildings, it is proposed that future servicing of vehicles should be done on the Station. Major works will be referred to the agents. A costing system will be introduced and comparison made with past years' expenses. If properly controlled much loss of vehicle time on the road will be saved and transport conditions improved. Vehicles are at present serviced at Ibadan, 17 miles away.

Vehicle strength on the Station comprises:

1 5-ton Thames Trader	(Diesel)
1 3-ton Thames Trader	(Petrol)
1 25-30-cwt. Bedford Pickup	(Diesel)
1 Land Rover	(Diesel)
1 Fordson Major Tractor	(Diesel)
1 Fordson Dexta Tractor	(Diesel)
1 Massey Ferguson 35 Tractor	(Diesel)

Plantings

Approximately 16 acres of Amazon and 3 acres of Amelonado seedlings were planted. Excessively low rainfall and a long drought period rendered the late Amelonado plantings a failure. Clearing for planting a further 18 acres of cocoa during the coming season is in hand.

Cocoa maintenance

Routine maintenance of young and mature cocoa was continued throughout the year and watering of young seedlings during the drought period was necessary.

Revenue

Sales of dried cocoa beans realized	£1,183	16	3
Other sales realized	220	8	1
Total sales	£1,404	4	4

Weather

The year has been an exceptionally dry one as indicated by the records (see Table 2).

Medical

Station development is progressing favourably, and the staff have worked well under poor conditions. The lack of reasonable medical facilities has been very much evident and the need for a dispensary with trained personnel and supervision is emphasized.

Plots Committee

The Plots Committee has met three times during the year. As a result, the blocks of cocoa soil at Gambari have been named, and those with cocoa trees on them have been divided up into numbered plots and the individual trials designated. A general plan of Gambari, and plans of the North, West and East blocks, are given in this Report.

VIRUS RESEARCH

MECHANICAL TRANSMISSION OF COCOA VIRUSES

(A. A. F. Brunt & R. H. Kenten)

Purification of swollen shoot virus

Although swollen shoot virus (CSSV) has been transmitted mechanically by inoculating cocoa with leaf extracts from infected cocoa and some other hosts (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 19) attempts to concentrate the virus by ultracentrifugation of such extracts were not successful. The reason for these failures is not clear since leaf extracts remain infective for several hours at room temperature (25-30°C).

Using infected cocoa leaves as source of virus it has been found that the addition of a little (0.25-2.0 per cent w/v.) soluble or

insoluble protein to the extraction fluid gives an extract from which the virus can be concentrated by ultracentrifugation. On most occasions preparations were obtained with relatively high infectivity as compared with that of leaf extracts which rarely gave greater than 1 to 2 per cent transmission. (Table 3).

TABLE 3

The effect of protein on the extraction of CSSV from cocoa

Extractant contained	Infectivity of ultracentrifuged preparation ^a					Total
	1	2	3	4	5	
No protein	0/75	0/39	0/38	0/33	0/40	0/225
Egg albumin	17/50	21/98	8/35	—	—	46/183
Blood albumin	—	18/36	—	—	9/40	27/78
Casein	—	—	4/38	9/39	—	13/77
Hide powder	—	33/39	22/78	—	20/40	77/157

^aThe inoculum was the pellet got by ultracentrifuging clarified extracts from cocoa leaves extracted with 0.05 M phosphate, 0.05 M thioglycollate, 0.005 M diethyldithiocarbamate (pH 8) with or without added protein. Cocoa beans were used as test plants.

The numerator indicates the number of infected plants and the denominator the number of test plants inoculated.

After freezing, thawing and clarifying by low speed centrifugation the once ultracentrifuged preparations can usually be further concentrated by high speed centrifugation. This step, however, has not always given more infective preparations.

THE EFFECT OF VIRUSES ON GROWTH AND YIELD OF COCOA

(J. W. Blencowe & A. A. F. Brunt, continued by N. K. Lovi)

In experiment A4 the relative effects of the Bosomuso, Dawa, Kpeve, New Juaben and Worawora isolates on growth and yield of young Amelonado cocoa, have been studied (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 22). Rates of infection, canopy deterioration, and pod yields have been recorded for three years.

The data shown in Table 4 indicate that every isolate had, by the end of the second or third year, infected 95 per cent to 100 per cent of the trees inoculated. The Kpeve and the New Juaben viruses caused the greatest deterioration of the canopy and most severely reduced the yield per tree in the third year. The Bosomuso and the Dawa isolates were intermediate in their effect, while Worawora was the mildest. The cocoa infected with Worawora, like the uninfected ones in the control, remained constantly vigorous throughout and produced the largest number of pods per tree.

The actual effect of each virus has thus been successfully assessed since capsid damage, which has often overshadowed the real

TABLE 4
Comparison of some effects of five virus isolates on young Amelonado cocoa

Isolates	1959-60			1960-61			1961-62		
	% Infected	Mean Canopy Density	Mean Pods/ Tree	% Infected	Mean Canopy Density	Mean Pods/ Tree	% Infected	Mean Canopy Density	Mean Pods/ Tree
Healthy Control	0	5.0	7	0	5.0	18	0	5.0	11
Worawora	42	5.0	15	95	4.9	24	99	4.8	20
Bosomuoso	89	4.8	11	100	4.4	14	100	4.3	11
Dawa	88	4.7	11	100	4.3	13	100	4.3	10
Kpeve	75	4.6	15	97	3.7	8	99	2.9	6
New Juaben	82	4.4	13	97	3.2	12	99	2.3	5

Maximum Canopy Density Score = 5

destruction done by these viruses in the field, was eliminated by spraying with gamma-BHC. Spraying, coupled with sanitation consisting of brushing of the under-growth, gave rise in the second year to increases in the yield of cocoa in the healthy control treatments and those which had been inoculated with the Bosomuoso and Dawa isolates. The Kpeve and the New Juaben isolates actually began reducing pod yield in the second year by which time the canopy of the cocoa infected had considerably deteriorated.

In experiment H2/3 the effect of the virulent New Juaben strain on growth and yield of Amazon and Amelonado cocoa with or without shade, has been compared. (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 22). The Amelonado cocoa was so highly susceptible to virus infection that all trees had become infected by the end of the second year and had developed many swellings. Infections in the Amazon cocoa were complete at the end of the third year.

In neither type of cocoa did the shade and canopy conditions appear to have affected the rates of virus infection. (Table 5).

Pod yield results for which figures are awaiting statistical analysis, will be included in next annual report.

In many cocoa growing areas, the simultaneous occurrence of virus infection and capsid damage is one of the principal causes of mortality in cocoa; but it has been difficult to determine which of these two factors was primarily responsible for the death of a tree.

To investigate this, an experiment was carried out on peasant cocoa of apparently different ages and of random spacing in swollen shoot outbreaks at Ampem, Enchi, Kofi-Pare and Mamfe. These four localities were selected to represent regions of diverse climatic conditions and soil types. The outbreaks in each locality were demarcated into a number of experimental plots.

There were fifty-six plots and the cocoa in twenty-eight of them was sprayed at monthly intervals with 2 oz. gamma-BHC per acre.

Canopies and death rates of the cocoa in both groups of plots were regularly assessed at three-monthly intervals. Pod yields were also recorded seasonally. Results indicate that elimination of capsids from the sprayed plots had not prevented the trees from deteriorating and dying. Nevertheless, decline has been slower than in the unsprayed plots where virus and capsids were associated. Statistical analysis of the general results, including pod yields, will be completed before a final conclusion is arrived at.

RESISTANCE AND TOLERANCE

(J. W. Blencowe & A. A. F. Brunt, continued by N. K. Lovi)

In the variety trial E1, canopies of the cocoa seedlings have been assessed and girths measured prior to inoculation of the Amelonado

TABLE 5
Infection and Canopy Deterioration compared in Virus — Fertilizer and
Virus + Fertilizer cocoa under shade or no shade

		Amazon				Amelonado			
		Shaded		Unshaded		Shaded		Unshaded	
		with fertilizer	without fertilizer	with fertilizer	without fertilizer	with fertilizer	without fertilizer	with fertilizer	without fertilizer
% Infection	1959-60	21	38	64	47	83	74	77	73
	1960-61	83	85	87	81	100	100	100	95
	1961-62	98	96	98	95	100	100	100	100
Mean	1959-60	4.9	4.9	4.8	4.8	4.6	4.7	4.6	4.5
Canopy	1960-61	4.8	4.6	4.5	4.7	2.6b	2.7b	2.9b	2.7b
Density ^a	1961-62	3.9	3.4	3.6	3.8	1.7c	1.5c	1.9c	1.3c

^aMaximum canopy density score = 5

^bCanopy largely defoliated, with many dead twigs

^cMany trees moribund

seedlings in the guard rows with virus. (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 26). The canopy is continuous and satisfactory. Spraying to control mealybugs will not be done, since spontaneous spread of the virus from the infected Amelonado seedlings in the guard rows into the varieties within the plot should be allowed. Subsequent assessments after inoculation will be carried out at three monthly intervals.

Similar pre-inoculation data have been gathered for the variety trials E2 and E3. Buds in E2 have not grown sufficiently for inoculation, but preparations are being made to graft-infect the seedlings in E3 with the Bisa, Kpeve, New Juaben and Worawora isolates of CSSV. Each isolate will be used to infect 60 seedlings of each of the selections T17/359 x T17/1219, T17/359 x T16/613 and Amelonado, contained in eighteen randomized plots. Sixty of each will be left as controls.

Swellings in Hildegardia barteri (Mast.) Kosterm, induced by cocoa swollen-shoot virus

Although some isolates of CSSV produce only transient leaf symptoms in cocoa they all produce stem swellings and leaf symptoms. About 40 related plants, including other *Theobroma spp.*, are susceptible to infection with CSSV but swellings have only been observed previously in cocoa.

We have found that *H. barteri* seedlings grown from seed collected near Ibadan, Nigeria produced pronounced stem swellings 3-6 months after infection with the Bosomuoso and Kofi Pare isolates of CSSV. No swellings were induced when seedlings of *H. barteri* grown from seed collected near Koforidua and Tafo, Ghana, were infected with CSSV isolates.

Histological examination showed that, like the virus induced swellings on cocoa, those on *H. barteri* arise from localised increases in xylem and phloem.

The seedlings grown from seed collected in Ghana and Nigeria are morphologically indistinguishable. Nevertheless, there must be some difference between the seed and plants from the two countries because of the different response to the same virus isolate.

BLACK-POD DISEASE

RESISTANCE AND TOLERANCE

Laboratory studies (P. D. Turner)

Work has continued on laboratory tests to distinguish between selections showing differential susceptibilities to *Phytophthora* pod rot (cf. *Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 28). Determination of

polyphenoloxidase production by various selections has shown that no significant differences could be found between 'resistant', 'intermediate' and 'susceptible' groups of selections, although a wide variation was found in enzyme activity of acetone powder preparations from individual selections, particularly between older tissues. The results, summarized in Table 6, showed that polyphenoloxidase activity was invariably greatest in cherelle tissue powders; in large immature and ripe pods activity was usually higher in external endocarp tissues. The results suggest that if polyphenols are contributory to resistance to infection, the decisive factor is unlikely to be the level of oxidative enzyme.

TABLE 6

Polyphenoloxidase activity of acetone powders, from ten pods of each selection, expressed as the mean time taken (mins.) to reach an optical density increase of 15 with filter 601

	Selection	Cherelle	Large Immature		Ripe	
			E.E.	I.E.	E.E.	I.E.
'Resistant'	D70	15	18	24	27	16
	Y44	25	37	38	36	41
	U6	20	21	24	30	31
	S27	25	24	32	23	25
	ACU85	11	26	30	30	28
	Mean	19	25	30	29	28
'Intermediate'	P30	16	31	32	43	41
	E1	20	19	23	45	80
	ICS1	23	30	34	NT	NT
	O2	22	26	34	37	41
	B1	19	34	37	NT	NT
	Mean	20	28	32	42	54
'Susceptible'	TF2	20	34	31	NT	NT
	A56	21	33	43	25	23
	A12	18	20	28	19	24
	A62	19	39	38	29	34
	R15	17	29	32	NT	NT
	Mean	19	31	34	24	27
Unselected						
Amelonado		17	17	18	28	36

E.E. = External endocarp pod tissue

I.E. = Internal endocarp pod tissue

N.T. = Not tested

Growth of the fungus on tissue extracts has been measured by the rate of colony development on agar plates and by the dry weight of mycelium produced in liquid cultures. For extracts of cherelles and external endocarp tissues 5.0 gm. of each tissue were macerated for 30 seconds in 200 ml. deionised water and filtered through cotton wool; 5 per cent extracts of internal endocarp tissues were prepared. For growth rate measurements 3 per cent agar was added and 15 ml. of autoclaved medium poured into each Petri plate. 20 ml. aliquots in 100 ml. conical flasks were used for mycelial dry weight assessments. In other dry weight tests, Czapek Dox salts containing thiamin and sucrose supplements were added. Standard inoculation of plates and flasks was made using cork borer discs from colonies of the fungus on plates containing 15 ml. of potato dextrose agar. Replicates of three aliquots of each tissue extract from each of 5 cherelles, large unripe, and mature pods were measured for colony diameter after 3 days and for dry weight after 4 days. The mycelium was filtered from liquid cultures onto previously weighed filter papers, dried at 90°C. for 4 hours, and weighed. The results, summarised in Table 7, showed no significant differences between selections in growth rates on tissue extract agar plates. The rate was slightly higher on tissue extracts of large immature pods than those from pods of other developmental stages. A similar situation was found with dry weight measurements (Table 8), although some indication was found of differences in growth on extracts of internal endocarp tissues of large unripe pods, particularly when the media were supplemented.

TABLE 7

Mean colony diameter (cm.) of P. palmivora on 3 per cent tissue extract agar after 3 days

<i>Disease incidence</i>	<i>Cherelle</i>	<i>Large Unripe</i>		<i>Mature</i>	
		<i>E.E.</i>	<i>I.E.</i>	<i>E.E.</i>	<i>I.E.</i>
High	5.6	5.8	5.8	5.0	5.1
Medium	5.8	6.0	6.2	5.9	5.7
Low	5.5	5.8	5.6	5.4	5.4
Unselected					
Amelonado	5.8	5.9	6.2	6.4	6.2

E.E. = external-endocarp tissue
I.E. = internal-endocarp tissue

TABLE 8

Mean dry weight (mgm.) of P. palmivora in tissue extract cultures after 4 days

<i>Disease Incidence</i>	<i>Soln.</i>	<i>Cherelle</i>	<i>Large Immature</i>		<i>Mature</i>	
			<i>E.E.</i>	<i>I.E.</i>	<i>E.E.</i>	<i>I.E.</i>
High	A	4.7	3.9	10.9	3.9	7.3
	B	13.6	16.7	46.9	—	—
Medium	A	5.1	3.4	10.6	4.0	7.8
	B	13.4	7.9	34.1	—	—
Low	A	4.3	3.7	8.6	3.0	5.6
	B	24.4	10.1	29.2	—	—
Unselected	A	5.8	3.9	11.4	3.1	5.6
Amelonado	B	16.1	13.5	34.8	—	—

A = water extract

B = supplemented medium

E.E. = external-endocarp tissue

I.E. = internal-endocarp tissue

A comparative study of lesion development and sporulation in a number of selections has also been made. Sporulation was measured on each of four pods after 3 and 4 days on cherelles, 4 and 5 days on large immature pods, and 4, 5 and 6 days on fully ripe pods, and on each occasion the lesion diameters were also measured. Inoculation of the fungus was standardised by using a cork borer to remove a tissue disc from each pod and filling the cavity with an equal-sized piece of diseased tissue from the lesion edge of a previously infected pod. Development took place in humid chambers of polythene sheeting over wire frames containing a little water to maintain a high humidity. Sporulation measurements for cherelles were made by washing surface mycelium and spores from whole lesions into 50 ml. of water containing 5 ml. of 0.01 per cent mercuric chloride solution to prevent sporangial germination; for measurements on the larger lesions in older pods a quarter of each lesion was cut away for each daily sampling. Sporangial production was calculated from haemocytometer counts, and assessments of the mean sporangial production per sq. cm. for each selection were made on the assumption that the lesions were approximately elliptical in shape. Sporulation on tissue extracts was also compared; 2 per cent external-, or 5 per cent internal- endocarp tissue was macerated for 30 seconds, filtered through cotton wool, and autoclaved at 15 lbs. pressure for 5 minutes after addition of 2 per cent agar. 10 ml. aliquots were poured into Petri plates, which were then inoculated uniformly and incubated at 25°C. Marked variation was found in lesion development and sporulation both between selections and between pods of different ages of the same selection. In general, as the pods matured lesion

size and sporulation decreased, and considerably less variation was found between lesions in mature pods than in younger stages of varieties of apparent differential susceptibility. Data are summarized in Table 9. Sporulation on cherelles and large immature pods of

TABLE 9

Lesion and sporangial formation by P. palmivora in cocoa pods of different selections

Disease Incidence	days	Cherelle		Large Immature		Mature		
		3	4	4	5	4	5	6
High	A	1.10	3.50	1.01	2.93	0.52	0.95	2.20
	B	—	—	13.04	19.12	9.18	12.66	14.29
	C	—	—	77.7	156.4	57.9	94.2	153.6
Medium	A	0.58	1.70	1.33	2.73	0.57	1.50	2.41
	B	—	—	14.04	19.19	11.94	18.47	19.01
	C	—	—	78.3	143.4	47.0	78.2	128.0
Low	A	0.56	2.22	0.24	0.82	0.52	0.89	2.37
	B	—	—	3.85	6.36	13.23	10.99	17.69
	C	—	—	64.1	130.0	48.3	81.8	138.2
Unselected	A	1.07	8.08	0.25	1.89	1.06	1.44	1.55
Amelonado	B	—	—	0.03	16.51	19.03	16.30	10.37
	C	—	—	62.1	114.7	55.8	88.2	149.5

A = mean No. of sporangia ($\times 10^6$) produced per lesion

B = mean No. ($\times 10^3$) per cm^2

C = mean area of lesions (cm^2)

selections showing a low disease incidence was significantly lower than those of 'susceptible' selections tested except that sporulation by lesions in cherelles of Y44 was comparatively high, and that of lesions in large immature pods of the selection showing the highest disease levels, R15, was low. Plate cultures showed that sporulation is largely controlled by the internal endocarp tissues, as very few sporangia were found on agar extracts of external tissues. This provided further indication that the most important factors conferring resistance or tolerance are operative in the post-penetration stage of infection.

ROOT INFECTION OF COCOA BY *PHYTOPHTHORA PALMIVORA* BUTL.

Infection of Amelonado seedlings

(P. D. Turner and E. J. A. Asomaning)

The widespread occurrence of *Phytophthora palmivora* in soils from cocoa plantations (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 30), and

TABLE 10
*Fresh and dry weight measurements of control and treated seedlings in sand culture
and sterilized soil eight weeks after inoculation with P. palmivora*

	Number of plants	Length (cm.)	Mean stem		Number	Mean leaf		Mean root	
			Fresh	Dry		Area (cm ²)	Weight (gm.) Fresh Dry	Weight (gm.) Fresh Dry	Weight (gm.) Fresh Dry
Sand Culture	Treated	23.4	2.5	0.6	8.5	30.4	5.0	1.4	3.0
	Control	29.1	4.3	1.0	12.3	48.5	10.0	2.8	0.7
	% Control	80.4	58.1	60	69.1	62.7	50.0	50.0	5.0
	Treated								77.8
Soil Culture	Treated	26.5	2.4	0.7	5.5	36.0	2.3	0.7	1.6
	Control	30.2	2.7	0.8	6.2	41.0	2.5	0.8	0.3
	% Control	87.7	88.9	87.5	88.7	87.8	92.0	87.5	2.2
	Treated								0.6
	Control								50.0

the casual observation that root systems of seedlings sown in those plantations are poorly developed, suggested that root infection might occur.

Amelonado cocoa seedlings were raised from beans in either acid-washed sand culture supplied with complete mineral nutrient, or in sterilized soil culture. After the first flush leaves of the seedlings had fully hardened, the surfaces of the sand and soil cultures were inoculated with a sporangial suspension of *P. palmivora*. The growth data summarized in Table 10 show the effects of the fungus which had retarded all aspects of growth recorded, although this was more pronounced in the seedlings raised in sand culture. In each type of culture the fungus was easily re-isolated from the infected roots.

Thus, in addition to attacks on the aerial parts of the cocoa plant, *P. palmivora* is now known to infect the root system. The focal point of attack by the pathogen appears to be the young growing points of the root. Since these are the regions closely associated with the uptake of mineral nutrients and water it is suggested that the adverse effects on growth caused by the pathogen arise principally through its effect in reducing the absorbing surface of the roots. Similar effects of *Phytophthora* spp. on the roots of *Pinus rafiata* have been described recently by Newhook (*Nature, Lond.*, 191, 615-616, 1961).

As the development of a seedling in the field is likely to depend upon its pre-planting history, routine use of sterilized soils in nurseries may prove beneficial.

Studies on varietal resistance to root infection

(E. J. A. Asomaning and A. L. Wharton)

Results from the experiment described above suggested a new approach to the problem of selecting varieties of cocoa that are resistant to *P. palmivora*.

On the assumption that resistance to *P. palmivora* may be a systemic physiological endowment, it was considered that a comparative study of the growth of seedlings of different cocoa selections following inoculation of the roots with the pathogen might yield a useful clue with regard to patterns of resistance to 'black pod' disease. This method, if successful, would be rapid and would provide information within a few months which normally takes years of field work to obtain.

As a result of field studies on mature trees some selections of cocoa have tentatively been grouped into types resistant or susceptible to 'black pod' disease (Table 11).

TABLE 11

Varieties of cocoa that are resistant or susceptible to 'black-pod' disease

'Black-pod' history	<i>Trinitario</i>	<i>Varieties Amelonado</i>	<i>Amazon</i>
Susceptible from field records	A 12 R 15A SC 1	Unselected	T79/467
Resistant from field records	S 27 ACu 85 D 70 U 6		T79/501 T60/887

A root infection study has been started to confirm the scheme shown in Table 11. Five rooted cuttings of each variety in sand and soil cultures respectively have been root-inoculated and an equal number of non-inoculated controls are also being maintained. A growth analysis of the plants up to five months will form the basis of the comparison of their differential responses to the pathogen.

MEALYBUG STUDIES

JOINT W.A.C.R.I./DIVISION OF AGRICULTURE ANT-MEALYBUG CONTROL TRIALS

(K. B. Armstrong)

The experiment on 10 acres of cocoa at Nankese and at Koransang (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 38) was terminated in March, 1962, a year after its inception. Heptachlor and chlordane were used in this experiment as possible alternative formicides to dieldrin, which gives rise to a marked increase in minor pests.

Fortnightly assessments of ant and mealybug populations showed that some degree of control had been achieved in that the total numbers of these insects had dropped following spraying. However, the number of trees infested by ants and mealybugs, which from its practical implications is the more important measure of the degree of control obtained, showed no significant decrease throughout the experiment.

Heavy damage by *Marmara* spp. was recorded between October and December on pods of the main harvest. This finding strengthens the possibility that ants might be predaceous on some immature stages of *Marmara* and that, after reducing ant numbers with insecticides, populations of these pod miners are able to build up.

The effect of BHC on ant populations

Two plots at Tinkong were sprayed with gamma-BHC at 4 oz. a.i. per acre in August and again, at 2 oz. a.i. per acre in September and December. Pre-treatment data showed that crematogasterine and camponotine ants occurred on both plots but that crematogasterine ants predominated on Plot 1 and camponotine ants on Plot 2. Pheidoline ants were present only on Plot 2.

The spray treatment, the same as that normally would be applied in routine anti-capsid spraying, disorganised the ant communities for about seven days in a non-specific fashion, but continued regular surveys of the plots showed that all the ant populations quickly recovered and no lasting treatment effect could be detected. Similarly no change in the existing mealybug populations was found, indicating that the initial upset in ant organisation was too small and of insufficient duration to affect ant-mealybug relationships.

Ecological studies

The experiment at W.A.C.R.I. (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 39-40) continues. Data collected from weekly samplings show that the populations of all species of mealybugs have increased on all of the sites.

Plot H₄ has been de-shaded and the inter-row vegetation on all four sites has been removed. Mealybug-attendant ants have different nesting habits, crematogasterine ants nest in dead branches, whereas camponotine ants are terrestrial nesting and, following the removal of inter-row vegetation, camponotine ants have greatly outnumbered the crematogasterine ants on the three sites which are surrounded by clean-brushed cocoa. However, on the site E₁, in part surrounded by forest containing many dead tree branches and stumps, crematogasterine ants far outnumber the camponotine ants. These differences in ant population can be seen from Table 12, which gives the number of mealybug colonies attended respectively, by crematogasterine and camponotine ants.

TABLE 12

Site	Examined	Number of mealybug colonies	
		Attended by crematogasterine ants	Attended by camponotine ants
E ₁	5570	4672	570
H ₄	2430	754	1220
N ₉	3272	289	2760
35 Acre	4825	1826	2896

E₁ } —Forest cover felled and laid in lines, inter-row vegetation removed.
H₄ }
N₉—Forest cover felled and removed, inter-row vegetation remains.
35 acres—As N₉ but with young *Terminalia ivorensis* planted as shade.

Other work

The biology of the ants associated with cocoa is being studied with the aim of providing a better understanding of the role these insects play in the ecology of other cocoa insects, including both known and possible pests. In the study detailed drawings of the various forms of the ant species are being made, these being essential for recognition purposes and hence for any satisfactory biological work along the lines planned.

CAPSID STUDIES

JOINT W.A.C.R.I./DIVISION OF AGRICULTURE CAPSID CONTROL TRIALS
(J. A. Dunn)

In laboratory screening tests, Armstrong (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 41) showed Sevin to be extremely effective against fifth instar nymphs of *Distantiella theobroma* (Dist.) but he failed to obtain a satisfactory level of capsid control with this insecticide in the field (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 42). The failure may have been due to heavy rain destroying any residual action of Sevin by washing off deposits from the sprayed trees. A pilot experiment was therefore established at Kwahu Tafo, where a new material (Lovo), which is capable of enhancing the performance of certain formulations of Sevin by extending the residual life of the spray droplets and deposits, was used with Sevin.

Pre-treatment capsid counts and canopy assessments were made and the plots, each two acres in size, were then matched as evenly as possible. Two levels of Lovo (twelve and six fluid oz.) were each used with 1½ lb. actual Sevin per acre and compared with a standard 4 oz. treatment of *gamma*-BHC. A single application of these treatments was made in early December, and four weeks later half the plots were again sprayed with the same respective materials but at one quarter of the respective rates.

Assessments of fresh capsid damage were made two weeks after the first spray application and at fortnightly intervals following the second spray application. These showed that in the early stages after spraying the Sevin/Lovo treatments seemed to be giving a very promising degree of control which was not much inferior than that given by the *gamma*-BHC treatment. Subsequently, however, it became apparent that, compared with *gamma*-BHC, Sevin/Lovo was giving a less lasting control of capsids. Further field work with Sevin/Lovo is planned.

POLLINATION STUDIES

(B. M. Gerard)

The collection of detailed, pre-treatment information about the flowering performance and the percentage setting on the trunks of each of 207 cocoa trees has continued. These trees are in an 8-acre plot (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 44). The plot is divided into 3 sub-plots, each of which will receive different insecticide treatments.

Adult ceratopogonidae, the chief pollinating midges in cocoa, are being collected by suction traps. It is hoped that an apparatus for determining both the daily and the seasonal distribution of the species of midges in the important genus *Forcipomyia*, will be completed during 1962.

MINOR PESTS

MARMARA STUDIES (B. M. Gerard)

Adults of three species of pod husk miner, *Marmara* sp., have been bred from the pupae found on cocoa trees. The majority belong to a species which occurs throughout the W.A.C.R.I. plantation. The second species has a more restricted distribution and the pupae have been found only on chupons. Only one pupa of the third species has been found. Studies on the life history of these pod miners are continuing.

It has been recognized that *Marmara* populations increase suddenly after cocoa is sprayed with dieldrin (Entwistle, Johnson and Dunn, *Nature, Lond.*, 184, p. 2040, 1959). At W.A.C.R.I. the two regions of high *Marmara* damage in 1961 were both centred on plots sprayed with dieldrin. The larval population of miners was found to be as high in plots receiving dieldrin as it was on plots which received no dieldrin, yet large numbers of pupae were found on trees in dieldrin treated plots but very few on the trees in the unsprayed plots. This suggests that, on untreated plots, the late instar larvae are killed by parasites or predators before the pupae are formed. The indications to date are that, under normal conditions, predators are more likely to be responsible for this larval mortality. It is very noticeable that ants are absent from dieldrin-sprayed areas and an experiment has been started to find whether more pupae are obtained from trees when ants are excluded than when ants are allowed full access. The study could show if ants are predaceous on the larvae of *Marmara* spp. and, if so, which species of ants are the most efficient predators.

Collections of more Lepidoptera of the family Lithocolletidae (syn. Gracilariidae) were made from plants common in cocoa plantations. The information will be useful in the event of any of the species extending its host-plant range to include *T. cacao*.

GENERAL STUDIES (B. M. Gerard)

Additions, especially of insects found in cocoa plantations, have been made to the reference collection of insects. Many Auchenorrhyncha (Homoptera) have been collected from *T. cacao* and adults of 15 species have been obtained from nymphs feeding on this host.

NEMATODE STUDIES

(Mrs P. M. Gerard)

Samples were taken from the roots of *T. cacao* and the following species of shade plants: *Musa sapientia* (banana); *Musa sapientia* var. *paradisziaca* (plantain); *Carica papaya* (pawpaw); *Terminalia ivorensis*; *Glyricidia* sp. and *Manihot* sp. (tree cassava), and from the surrounding soil.

The species of nematode found associated with *T. cacao* are given in Table 13.

TABLE 13

Nematodes associated with cocoa roots

<i>Found in both soil and root samples</i>	<i>Found only in soil samples</i>
<i>Helicotylenchus multicinctus</i>	<i>Tylenchorhynchus</i> spp.
<i>Helicotylenchus</i> spp.*	<i>Xiphinema nigeriense</i>
<i>Criconemoides</i> spp. (2 species found)	<i>Xiphinema</i> sp. (infacolum ?)
<i>Paratylenchus</i> spp.	<i>Xiphinema</i> sp. (ebriense ?)
<i>Meloidogyne incognita acrita</i>	<i>Xiphinema</i> spp.
<i>Meloidogyne</i> sp.	<i>Trichodorus</i> spp.
<i>Pratylenchus</i> spp.	<i>Hoplolaimus</i> sp. (proporicus ?)
<i>Aphelenchus</i> sp.	<i>Hoplolaimus</i> spp.

*One new species of *Helicotylenchus* is being described in America by S. A. Sher

Nematodes common to the roots of cocoa and banana and plantain were *Helicotylenchus multicinctus*, *Helicotylenchus* n. sp., *Helicotylenchus* spp., *Meloidogyne* sp. and *Pratylenchus* spp. Those on cocoa and pawpaw roots were *Helicotylenchus multicinctus* and *Meloidogyne* sp. (*incognita acrita*?). *Glyricidia* sp. had a very few *Paratylenchus* sp., and only one adult *Paratylenchus* sp. was found on tree cassava.

Hoplolaimus sp. (*proporicus*?) was obtained from banana and plantain roots but not from cocoa. No nematodes were found associated with *T. ivorensis*.

Species of the genus *Helicotylenchus* were found in 32 of the 38 plots sampled at W.A.C.R.I. They were found in large numbers in soil samples taken close to banana and plantain, and in most cases the numbers obtained from the base of cocoa trees were found to be inversely proportional to the distance from the nearest banana or plantain. The maximum number of *Helicotylenchus* spp. obtained was estimated to be 330 per litre of soil from a tree in F.1 plot. As *Helicotylenchus* spp. are known to be parasitic on plant roots the high populations found in association with banana and plantain might have an injurious effect on cocoa growing in the shade of these plants.

Pot experiments to find which species can live successfully on *T. cacao* and what effect they have on plant growth have been started using *Helicotylenchus* spp. and *Meloidogyne incognita acrita*.

Seven species have been found in root and soil samples taken from virus infected cocoa trees. Investigations into the possibility of these species acting as vectors of cocoa viruses have been started.

ESTABLISHMENT AND MAINTENANCE EXPERIMENTS (T. H. R. Hall)

SPACING EXPERIMENTS

Amelonado cocoa

The yields for the fourteenth year of the Amelonado Spacing Trial are shown in Table 14.

The yield pattern follows that of the previous two years except that the 4 ft. $\times$ 4 ft. spacing has not performed quite so well as the other high density populations. Over the whole of the experiment there was a mean decrease of 19 per cent from the 1960-61 season, but in the very close spacings, almost 30 per cent decrease was recorded. The very dry conditions prevailing during the first five months of 1961 was the main contributory factor in this decreased yield although a heavy infestation of mistletoe which developed during 1961, possibly as a result of removing overhead shade, has also had its effect. This has since been cut from the trees.

The 1960-61 yields of this trial show that when favourable conditions are obtained, high yields can be expected from high density plantings. It is concluded from this year's result that when the nutrient status of the soil is upset, as happens during dry conditions,

TABLE 14
Yields from the Amelonado Spacing Trial

Spacing Equivalent Density (trees per acre) Pods per tree	15'×15'	12'×12'	10'×10'	7½'×7½'	7½'×6'	6'×6'	5'×5'	4'×4'
1960-61	193	302	435	774	968	1,210	1,742	2,722
1961-62*	101.0	102.8	76.6	44.6	34.4	29.0	19.9	12.9
Dry cocoa per acre (lbs.)	89.3	87.7	64.8	39.4	27.7	23.0	16.1	10.1
1960-61	1,623	2,588	2,765	2,878	2,765	2,897	2,894	2,929
1961-62**	1,436	2,063	2,350	2,543	2,225	2,319	2,333	2,288

*L.S.D. 52.0 pods at 1 per cent level

**L.S.D. 605 lbs. at 1 per cent level

TABLE 15
*Amelonado spacing trial - distribution of crop.
Percentage of total pods in canopy and trunk*

Spacing	15'×15'	12'×12'	10'×10'	7½'×7½'	7½'×6'	6'×6'	5'×5'	4'×4'	Mean
Trunk									
1960-61	39.2	35.6	38.7	48.7	61.0	63.4	70.2	74.7	44.5
1961-62	21.0	25.6	33.1	51.5	57.3	64.9	79.5	88.7	36.1
Canopy									
1960-61	60.8	64.4	61.3	51.3	39.0	36.6	29.8	25.3	55.5
1961-62	79.0	74.4	66.9	48.5	42.7	35.1	20.5	11.3	63.9

TABLE 16
Yields from the Upper Amazon spacing and pruning experiment

Spacing Equivalent Density (trees per acre)	8' × 8'		10' × 10'		12' × 12'	
	1960-61	1961-62	1960-61	1961-62	1960-61	1961-62
<i>Unpruned</i>						
Pods per tree	32.1	31.9	53.4	50.8	91.7	78.6
Dry cocoa per acre (lb.)	1,818	1,810	1,936	1,840	2,308	1,966
Percentage of crop in canopy	60.0	64.0	66.1	62.9	71.6	80.2
<i>Pruned</i>						
Pods per tree	27.4	19.4	53.0	32.9	68.6	32.7
Dry cocoa per acre (lb.)	1,555	1,104	1,920	1,191	1,721	823
Percentage of crop in canopy	57.1	55.9	71.4	76.6	70.9	75.8

then close spaced cocoa is affected to a greater degree than cocoa at lesser densities.

The distribution of the crop between the trunk and canopy shown in Table 15 is of a different pattern to the previous year. No conclusions are attempted in view of the high mistletoe infestation in the canopy, and as no definite pattern is emerging from the records. Weights of pods from main crop harvestings from trunk and canopy show the same percentage differences.

Two outbreaks of swollen shoot disease were cut out in the experimental area during the year.

Amazon cocoa

In three blocks extensive damage was caused by falling trunks of large dead trees. In three plots in two blocks, where growth was poor as a result of impeded drainage, the trees were cut back and temporary nurse shade planted. The yields in this trial are shown in Table 16.

The substantial reduction in the yield of the pruned cocoa is due to the fact that chupon growth has been allowed to develop following a decision to discontinue the pruning treatments. The overall reduction in yield over the whole experimental area is due in the main to the damage referred to above and to the adverse dry conditions prevailing during the first five months of the year.

The five acre area of F2 Upper Amazon cocoa adjacent to the spacing trial, referred to as the multiplication plot, is a duplicate of the spacing treatment. The yields recorded showed that the yield in the 8 ft. $\times$ 8 ft. was superior at the five per cent level of significance. The higher yields of this area, shown in Table 17, are a reflection of the severity of the damage in the formal spacing trial area in consequence of which this multiplication area will in future be used to study the effect of spacing in Amazon cocoa.

TABLE 17

Yields from the Multiplication Plot (B2) in lbs. dry cocoa per acre 1961-62

Spacing	8' $\times$ 8'	10' $\times$ 10'	12' $\times$ 12'
Population density equivalent	680	435	302
Pods per tree	34.1	47.5	58.7
Dry cocoa per acre (lb.)	1,950	1,722	1,478

PRUNING EXPERIMENTS

Amelonado cocoa

In the Second Establishment Trial and the Pruning Trial a significantly higher yield was obtained from the unpruned cocoa

than from the pruned cocoa. In both experiments the increasingly superior performance of unpruned cocoa is demonstrated.

Amazon cocoa

Since the pruning treatments on the Amazon spacing trial have been discontinued, the tree forming experiment is the only current study on pruning of Amazon cocoa. In this experiment the pruned cocoa gave a mean yield of 640 lbs. per acre compared with 500 lbs. from unpruned cocoa, the difference not being significant. The cocoa canopy is almost complete in the unpruned cocoa, while gaps in the pruned cocoa canopy still persist.

SHADE EFFICIENCY EXPERIMENT

By the end of March all temporary shade had been removed since the cocoa canopy was virtually closed under all shade regimes. Plots on the edge of the experimental area received a severe set back due to exposure following the clear felling in Blocks E and F.

The first yields were realized during experiment's third year since planting and these are shown along with other results summarized in Tables 18 and 19.

TABLE 18
Shade efficiency experiment - Table of results 1961-62

<i>Type of nurse shade</i>	<i>Plantain</i>	<i>Banana</i>	<i>Tree cassava</i>	<i>Tree cassava and plantain</i>	<i>L.S.D. at 5% level</i>
Mean diameter of trees 5 cm. above ground level on 3/11/59 (cm.)	0.93	1.02	0.97	0.97	0.07
Mean diameter of trees 5 cm. above ground level on 5/4/62 (cm.)	6.6	6.3	6.7	6.5	N.S.
Mean increase in diameter between 3/11/59 and 5/4/62 (cm.)	5.7	5.3	5.8	5.6	0.16
Mean diameter of trees 5 cm. above ground level on 26/9/61 (cm.)	5.7	5.5	5.9	5.6	N.S.
Mean increase in diameter between 26/9/61 and 5/4/62 (cm.)	0.93	0.87	0.79	0.94	N.S.
Mean fresh weight of weed growth cut during 1961-62 (lb.)	15.0	12.0	13.8	14.7	N.S.
Mean fresh weight of weed growth since 6/9/60 (lb.)	60.2	45.2	74.3	68.4	17.8
Number of trees producing second chupon tier	38	49	47	40	2.3
Yield dry cocoa per acre (lb.)	43	32	37	41	N.S.

TABLE 19

Shade efficiency experiment: soil moisture content (per cent)

<i>Type of shade</i>	<i>Plantain</i>	<i>Banana</i>	<i>Tree cassava</i>	<i>Tree cassava and plantain</i>
December 1961	13.7	16.8	15.2	16.3
January 1962	12.0	13.2	15.0	11.1
February 1962	10.4	13.1	11.4	10.5
March 1962	19.5	20.2	19.2	19.3
<i>Mean</i>	13.9	15.8	15.2	14.5

L.S.D. at 10 per cent = 1.31

With the closing of the cocoa canopy the weed growth was greatly reduced with the result that there were only minor differences in weed weights recorded. Under banana shade there is a greater tendency to produce a second tier of chupon growth. Other observations at Tafo have indicated that unshaded Amazon cocoa is slow to develop beyond the first jorquette. It is suggested that where Amazon cocoa is grown under a dense shade phototropic influences induce the seedling to throw up a second tier chupon.

MANAGEMENT STUDY OF CLONAL COCOA

The severe dry weather in the first five months of 1961 took a heavy toll of the cutting material, and despite mulching and watering, about 25 per cent replacements were necessary. With a satisfactory distribution of rain in the 1961-62 dry season, there were no deaths, though there were few instances of defoliation.

It has become obvious that for clonal cocoa a more intensive establishment husbandry is demanded. The surface rooting characteristics of fan clonal material may necessitate dry season watering, an expensive operation which cannot always be justified where seedling planting material is used and losses are consequently less. The planting of clonal material in West Africa at present will probably be restricted to seed gardens in which, since the value of the seed crop is very much higher than its commercial counterpart, the high establishment costs may be justified.

EXPERIMENTS PLANTED 1960

Deaths were replaced in the Thinning Trial and the 1960 planting of the Hybrid Shade and Manurial Trial. Routine weeding and nurse shade control was carried out at regular intervals and a small crop was realized from both experiments.

NEW EXPERIMENTS PLANTED 1961

As the number of pods from controlled pollinations did not come up to expectations there was sufficient planting material to complete only five acres of the second block of the Hybrid Shade and Manurial.

Two and half acres containing hybrids II H (S84: E104/90 $\times$ T85/991) and its reciprocal II J and two and a half acres containing hybrids II K (W41 $\times$ T63/067) and its reciprocal were planted. Because of the severe and prolonged dry season planting was delayed until the beginning of July. Possibly due to the fact that very heavy rain was recorded at Tafo during June, losses immediately after planting were of the order of 20 per cent, the majority of the seedlings which died being located on the low lying areas which were subject to water-logging.

REGENERATION OF THE OLD STATION

In many areas of Ghana, where cocoa has been cultivated for some time, yields are tending to decline. Diseases, pests and soil exhaustion are the more apparent factors contributing to this decline while senility, though more difficult to assess than others, plays a very important role. By any standards, these declining farms are not economical and, unless their rehabilitation or re-development can be achieved, they will cease to exist. Where soil fertility has not been allowed to deteriorate to a low level good husbandry, involving the latest advances in agronomy, may bring these moribund farms back into productivity. Poor soil conditions may or may not be alleviated by the judicious use of fertilizers.

Preliminary studies of the yields of the Old Station at Tafo show that, even with the introduction of chemical control of capsids, they are declining and that the tree population has been reduced to about 50 per cent of that in 1938. As this cocoa is typical of that to be found in many native farms in Ghana, a demonstration of different methods of regeneration was laid down in January 1962 to show different methods of rehabilitating or regenerating a cocoa farm which are within the means of the Ghanaian farmer.

Methods of regeneration to be studied

Hybrid planting material to be used where:—

- (i) the land is clear felled, the logs to remain where they fall,
- (ii) dominant trees only are felled leaving a proportion of sub-dominants as shade for cocoa,
- (iii) sub-dominants are felled leaving only one or two dominants per acre,

- (iv) underplanting where some of the original cocoa remains,
- (v) thinning of shade as far as possible without damaging the cocoa and the reduction of multi-stemmed mature cocoa to one trunk and thereby encouraging the development of basal chupons. Later (possibly after 3 years) the remaining trunk could be removed as well as selective thinning of the chupons,
- (vi) budding on hybrid material,
- (vii) complete coppicing.

In all methods the effect of fertilizer application and its absence will be investigated. The area to be occupied by each treatment will not be less than 1 acre.

Method of operation

The areas to be used for this demonstration are those quarter-acre plots which are now yielding at a rate of less than 600 lbs. per acre, but having given an average yield of more than 600 lbs. per acre. An essential feature of the demonstration will be the maintenance of a debit and credit costing record in which all expenditure in labour and materials and all revenue will be shown. It is vital that this demonstration should show to the farmer that these methods are within his capabilities and that additional financial and mechanical resources and skill are unnecessary. The project is run by a Senior Technical Assistant as the equivalent of the modern cocoa farmer. Within the framework of the project he is allowed to use his discretion as to timing of the employment of additional skills and the type of planting material to use, e.g. seed at stake or seedlings.

VEGETATIVE PROPAGATION

Cutting production potential of cocoa clones

The assessment of the cutting production potential of those clones already established in the clonal nursery continued; the results up to the end of March 1962 are shown in Table 20.

Though the order of superiority displayed in March, 1961 (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 55) has been altered in some respects, T79/416 and T9/67 have maintained their commanding lead over all others while Clones D4/4/4, P4/9 J11: 45 and E1: J92/70 remain poor performers. T60/886, an Amazon clone, is adjacent to a plot of clones which, because it was not included in the experiment, was not cut back with the others. Consequently the border effect of this clone is reflected in the low placement of T60/886, which from practical experience is a prolific producer of cuttings. It is considered that had this restricting effect of its uncut neighbour not been

present, T60/886 would have been comparable in performance to the other Amazon clones which are found in the upper part of the table.

TABLE 20

Cutting production experiment: number of cuttings from 20 trees

Clone	Number of cuttings taken before 31/3/61 at:			Number of cuttings taken since 1/4/61 at:			Total number of cuttings since August 1960 taken at		
	Weekly Monthly		Total	Weekly Monthly		Total	Weekly Monthly		Total
	inter- vals	inter- vals		inter- vals	inter- vals		inter- vals	inter- vals	
T79/416	2112	1972	4084	1668	1653	3321	3780	3625	7405
T9/67	2185	1828	4013	1270	1864	3134	3455	3692	7147
T79/501	1724	1379	3103	1068	1092	2160	2792	2471	5263
T9/21	1353	1087	2440	573	997	1570	1926	2084	4010
SC1	1067	1279	2346	689	823	1512	1756	2102	3858
Tf1	1339	988	2327	877	946	1823	2216	1934	4150
T60/887	1150	1161	2311	1048	1060	2108	2198	2221	4419
T12/26	1156	1040	2196	919	1085	2004	2075	2125	4200
U11	1308	882	2190	799	680	1479	2107	1562	3669
E9:B31/195	1110	1021	2131	593	848	1441	1703	1869	3572
R15	1189	862	2051	681	914	1595	1870	1776	3646
Tf1/148	1100	951	2051	739	842	1581	1839	1793	3632
B2	1023	895	1918	613	670	1283	1636	1565	3201
X40/1452	1106	765	1871	591	657	1248	1697	1422	3119
N38	801	823	1624	439	549	988	1240	1372	2612
Tf2	677	927	1604	571	877	1448	1248	1804	3052
E1 Clone	734	800	1534	324	440	764	1058	1240	2298
S27	390	1061	1451	227	838	1065	617	1899	2516
N38/91	805	479	1284	549	426	975	1354	905	2259
S36	663	480	1143	307	432	739	970	912	1882
Tf1/116	593	526	1119	251	344	595	844	870	1714
W41	629	482	1111	352	350	702	981	832	1813
Tf2/331	748	355	1103	589	430	1019	1337	785	2122
T60/886	635	441	1076	615	381	996	1250	822	2072
E1:C43/270	595	461	1056	331	320	651	926	781	1707
E1:C43/291	655	358	1013	365	222	587	1020	580	1600
E1:J92/70	319	550	869	209	379	588	528	929	1457
A196	471	380	851	327	338	665	798	718	1516
P4/9 J11:45	459	385	844	335	400	735	794	785	1579
Con D4/4/4	343	431	774	160	351	511	503	782	1285
Totals	28439	25049	53488	18079	21208	39287	46518	46257	92775

Cutting production of each clone

L.S.D. up to March 1962 at $P = 0.01$ is 478

Time of taking cuttings

L.S.D. up to March 1961 at $P = 0.01$ is 3231

up to March 1962 not significant

L.S.D. 1961-62 at $P = 0.01$ is 2842

Interactions between cutting times and clones were not significant

For the first eight months the taking of cuttings at intervals of one week proved to be the best. However, during the following twelve month period, 21,208 cuttings were obtained on a monthly cycle while only 18,079 from a weekly cycle, the difference being significant ($P = 0.01$). Over the whole period during which cuttings were

taken the difference between the monthly and weekly takings was not significant.

It is concluded that cuttings can be taken from the majority of clones as and when required and preferably at times which are phased with the flushing cycle. However for maximum short term production, cuttings can be taken at weekly intervals from all clones except S27, though in the long term only T79/501, Tf1, U11, T60/886 can tolerate continued clipping. A large number of cuttings can be obtained at monthly intervals from SC1, Tf2 and S27.

Rooting potential of W.A.C.R.I. clones

The cuttings obtained from the experiment described above were utilized in assessing the rooting response of each clone. Two hundred cuttings were set in semi-rotted sawdust cores in earth-filled polythene planting bags. Propagation was carried out by the methods devised by Archibald and McKelvie (*W.A.C.R.I. Tech. Bull. No. 3, 1955, Addendum*). It is not yet possible to make a final assessment of the rooting responses, since the rooting of some clones has not been completed. The results of both experiments will be discussed at length elsewhere.

Propagation of clones used in black-pod disease studies

A simple pilot experiment was laid down to determine the effect of sterilizing the rooting medium on the rooting response of clones which figure prominently in black-pod disease resistance studies. Because insufficient suitable material of the clones under test was available, the results are not amenable to statistical analysis. However it will be seen from Table 21 that further investigations into the desirability of sterilizing the rooting medium are indicated. It is

TABLE 21
Rooting response of black-pod disease resistant clones

Clone	Percentage rooting	
	In sand	In sterilized soil
SC1	15	45
A12	43	73
ACU 85	50	48
S27	25	40
U6	65	55
D70	48	75
R15	43	75
T60/887	8	58
T79/501	50	70
Amelonado	3	13
T85/799	15	55
T79/467	80	48

interesting to note the higher results obtained from sterilized soil in view of the observations made by Pyke (*Ann. Rep. Cocoa Res. Trinidad*, 1932). The results obtained are lower than are normally obtained when palm fibre and sand and sawdust are used as rooting media.

NURSERY TRIALS

Transport of cocoa seed out of the pod

The bulk transportation of cocoa seed in the pod is costly and efforts have been made to dispatch seed out of the pod. Preliminary work carried out by Nwachuku along lines, suggested by work in South America, indicated that viability was not impaired to any marked degree for 21 days after removal from the pod if the mucilage was washed from the seed, the final washing being in a weak solution of mercuric chloride. On this basis two series of experimental consignments of seed from 250 pods were dispatched to Ibadan where they were sown. The seed was packed in polythene after two hours sun drying. The experiment continues.

Use of polythene bags for raising cocoa seedlings

The growth of Amazon seedlings in baskets, polythene bags and 'whale-hide' pots was compared in order to determine the relative merits of each. The seedlings were grown under normal conditions at W.A.C.R.I., light shade being provided with uniform water application as and when required. Moisture determination in each of the containers clearly indicated the superior water retaining ability of the polythene bags which was 31.5 per cent as compared with 11.2 per cent for baskets and 11.6 per cent for 'whale-hide' pots. It has been observed that polythene bags displayed greater durability than others after nine months in the nursery. From the results shown in Table-22 it will be seen that there is little or no difference in the seedlings produced in each container. The low cost of polythene bags compared with the others is an important factor in their favour.

TABLE 22

Dimensions of seedlings grown in 'whale-hide' pots, baskets and polythene bags

Container	Height (cm.)	Diameter 2" above ground (cm.)	Mean number of of leaves		Mean length of roots (cm.)	Mean fresh weight of roots (gm.)	Mean fresh weight of stem and leaves (gm.)
			Hardened	flush			
Polythene	27.7	0.62	10.0	1.3	31.1	7.2	12.7
Basket	32.0	0.62	10.4	1.6	28.0	6.8	14.0
'Whalehide' pot	29.3	0.62	10.9	1.5	25.8	7.4	14.9

BLACK-POD RESISTANCE AND TOLERANCE

Field investigations

The remainder of the five acres field trial at Mpraeso (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 28) was planted in June, 1962, as were replacements of deaths from the 1960 planting. An N.P.K. fertilizer dressing was applied. Insecticides were applied at monthly intervals and weeding was continued. The tree cassava (*Manihot* sp.) temporary nurse shade has been developed into a tall hedge between the cocoa rows by lopping all lateral growth. Growth has been disappointing especially in the guard row selection A12-selfed which suffered from leaf infections of *Phytophthora palmivora* Butl.

SEED GARDEN

The growth of the parent cutting material has been slow but nevertheless satisfactory. Despite watering during the dry season, both plots suffered a serious set back and defoliation was noted in a number of plants. An N.P.K. fertilizer dressing was applied in April. Regular maintenance kept weed growth in check while insecticidal sprays were applied at monthly intervals. A small crop was realized at the end of the year.

PLANT BREEDING AND SELECTION

(D. R. Glendinning)

Following on a protracted dry season early in the year the mid-crop was rather spread and difficult to harvest, and the main-crop was late with its peak in January 1962. Disease losses were heavy over the mid-crop and earlier part of the main-crop.

Relative to last year the totals of pods harvested were lower in some plots and higher in others (Table 23). Yield was especially disappointing in the 9th progeny trial. Two reasons may be suggested

TABLE 23

Numbers of pods harvested from some of the main Botany plots (experimental areas only)

	<i>Year planted</i>	<i>Area (acres)</i>	1959-60	1960-61	1961-62
1st Clonal trial	1947	4.4	65,000	51,000	58,000
2nd Clonal trial	1948	2.8	39,000	22,000	30,000
8th Progeny trial	1952	1.9	31,000	31,500	30,000
9th Progeny trial	1954	5.2	89,000	93,000	52,500
3rd Clonal trial	1956	5.1	14,500	21,500	20,000

for this; firstly the plot is now very exposed due to clearance of adjoining land and the effects of the drought may have been particularly severe because of this; secondly there has been severe *Marmara* infestation in the plot as a result of dieldrin having been used to control insects in a nearby virus experiment, and this may have been damaging to the canopy. Yields in the 3rd clonal trial, which is alongside the 9th progeny trial and similarly exposed, were also disappointing, to which severe pruning of low branches may have been a further contributory cause.

In the 9th progeny trial, in spite of its poor general performance, and also in the 8th progeny trial, the general superiority of the hybrid varieties remains quite apparent (Table 24).

TABLE 24

General comparison of new hybrids, Amazons and Amelonado, etc.; 8th and 9th progeny trials, 1961-62

	8th progeny trial		9th progeny trial	
	Number of trees	Yield lb./acre	Number of trees	Yield lb./acre
<i>Amazon</i> × <i>Amelonado</i> hybrids	144(4)	2050	720(4)	1290
<i>Amazon</i> × 'local type' hybrids	288(3)	1720	720(4)	1210
<i>Amazon</i> types	288(3)	1140	180(1)	840
<i>Amelonado</i>	288(2)	1110	—	—
'Local types'	144(1)	1150	180(1)	600
	144(1)	290		

Potential yields, before deduction of disease losses, are shown. The performances of the two 'local types' in the 8th progeny trial were thought to be too dissimilar for them to be pooled. The number of trees is the total number of that general type in the trial; the number of varieties concerned is shown in brackets.

Table 25 shows the yields of some individual varieties.

The average pod-weight has been lower than usual this year, for example in the 8th P.T.A. it was only 91 gm. relative to 106 gm. last year, a reduction of 14 per cent. In preparing Table 25 weight per pod was estimated at 14 per cent less than the average for the period 1954-59 and for the 1958-59 season for the first and second clonal trials respectively, since cocoa from these trials is no longer weighed. For the approved types T60, T79 and T76 the estimated weight per pod was similarly reduced to 85 gm., 85 gm. and 94 gm. per pod respectively.

TABLE 25
Performance of some selections, 1961-62

	Spacing	Age from planting out (years)	Estimated yield dry cocoa (lb./acre ⁽¹⁾)	
			Potential	Net
<i>Trinidad Introductions</i>	14' × 14'	17		
T56			1700	1400
T6			1700	1200
T30			1400	1200
T60 ⁽²⁾			1500	1100
T79 ⁽²⁾			1500	1100
T76 ⁽²⁾			1600	1000
<i>Clones</i>				
1st Clonal trial ⁽²⁾	10' × 10'	15		
ACu85			2100	2000
A36			2100	1900
K5			2100	1800
2nd Clonal trial ⁽²⁾	8' × 8'	13½		
R15			1900	1450 ⁽³⁾
U6			1700	1400
TF1			1800	1400
D70			1700	1300
3rd Clonal trial	12' × 12'	6		
ACu85			510	400
T79/501			530	350
R15			580	260 ⁽³⁾
T12/113			500	130 ⁽⁴⁾
<i>Crosses</i>				
8th Progeny trial ⁽⁵⁾	8' × 8'	10		
WAE4			2700	1800
WAE5			2000	1400
WAE2			1800	1200
WBE4			1800	1100
9th Progeny trial	10' × 10'	8		
WAE11			1600	1000
WEA3			1300	800
WEB1			1200	700
WEB3			1400	600

Notes: (1) Except as noted in (2) below, dry weights are based on an assumed conversion rate of 40 per cent from weighed wet to dry fermented beans. Potential yields are based on all pods harvested; net yields are estimated after deduction of all diseased or damaged pods.

(2) Estimated from pod numbers (see text).

(3) R15, though not this year very severely affected in the 2nd clonal trial, is usually very severely attacked by black-pod; c.f. the 3rd clonal trial.

(4) T12/113 was severely attacked by rodents.

(5) WAE2, WAE4 and WAE5 in the 8th progeny trial are represented by one 36-tree plot each; WBE4 by four such plots.

FLAVOUR OF COCOA VARIETIES

Samples of cocoa from Series II varieties were submitted to the British and American manufacturers and to one Swiss firm during 1960. In the general British report all were classified as of West African type, though sometimes with slightly critical comments; WBE6 and WEB3, which are genetically alike, received the best comments. Some slight disagreements between individual firms

could be detected; thus while three firms passed all the samples as 'West African' two firms were rather more critical, though they did not fully agree with each other, the less critical of the two rejecting one sample which the other had passed while accepting many which the more critical firm had rejected or classed as 'borderline'.

The Swiss firm compared the samples to a West African standard on a statistical basis and succeeded in distinguishing all but two of them, these being WEA₂ and WBE₄; WEA₂ had been passed by all the British firms while WBE₄ was passed by four firms and classed as borderline by the most critical firm. Subsidiary comments on these samples in the general British report were not especially favourable: WEA₂, 'West African type but tending to weaker chocolate and rather too fruity'; WBE₄, 'West African type showing some degree of underfermentation'. WBE₆ and WEB₃, the samples most liked by the British, were distinguished by the Swiss from their standard at the 95 per cent and 99 per cent levels of certainty respectively.

The American manufacturers allocated numerical scores to the samples. Five firms reported, and no overall agreement between them could be established statistically; however a measure of agreement could be demonstrated between three firms, one of the other two being well out of agreement with them and giving almost significant negative correlations. This last firm appeared to be most in agreement with the British, in particular being the only firm which placed WBE₆ and WEB₃ relatively highly. However it also happens that this firm gave the lowest overall scores to the series as a whole.

In face of this substantial measure of disagreement between countries and between firms within a country it seems impossible to say which of the varieties are best. It would seem in fact that different firms have different preferences within the 'West African' flavour range. However these differences refer to matters of detail, and it can be said in general that none of the reports on Series II varieties were markedly unfavourable, and from the flavour point of view they appear suitable for issue.

SMALL FIELD EXPERIMENTS

Comparison of individual Amazon types and inter-Ama- zon hybrids as parents

The experiment, known as N13/3, compares Na₃₂ × Amelonado, Pa₃₅ × Amelonado, and (Na₃₂ × Pa₃₅) × Amelonado. It was planted in 1959. Data collected up to May 1961 indicates that Na₃₂ × Amelonado is about equal to (Na₃₂ × Pa₃₅) × Amelon-

ado, while Pa35 $\times$ Amelonado is inferior. Table 26 shows this for stem diameters; the evidence from leaf-numbers is similar.

TABLE 26
Stem diameters in experiment N13/3

	May 1961	Increase from Jan., 1960 to May, 1961
Pa35 $\times$ Amelonado	4.46 cm.	3.18 cm.
Na32 $\times$ Amelonado	5.26 cm.	3.75 cm.
T63 $\times$ Amelonado	5.24 cm.	3.67 cm.
Least significant difference at 1 per cent level	0.54 cm.	0.44 cm.

Note: T63 is Pa35 $\times$ Na32

Inter-Amelonado hybrids

A trial of crosses between Amelonado and Amelonado-like varieties, known as N13/4, was also planted in 1959. All crosses are outgrowing the ordinary Amelonado inserted as 'controls', though in general the performance of the trial is much inferior to that of the Amazon-Amelonado hybrids in experiment N13/3 alongside. Whether a measure of 'hybrid vigour' is being obtained in these crosses, or whether their superiority to the 'controls' is due entirely to selected Amelonados having been used as parents, is unknown.

NURSERY EXPERIMENT 1960-61

Following on experiments in previous years (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 52-55) a further experiment was carried out in 1960-61. Again the system used was to compare each variety with ordinary Amelonado, and in this case equal numbers of experimental seedlings and Amelonado 'control' seedlings were used, experimental and 'control' seedlings being intermingled on a grid system. Normally 24 seedlings from each experimental pod were used; a number of the crosses were represented by several pods each. Growth rates of each pod-progeny were expressed relative to those of the Amelonado seedlings, and three methods of estimating the growth-rates were used. One was based on the increases in stem diameter between March and July 1961, one on the increase in wet-weight from sowing of the beans to harvesting of the seedlings at the end of September 1961 and, where a quantity of seed had been available in excess of that required for sowing, one was based on the increase in dry weight from sowing to harvesting. Sowings were made at four dates; Table 27 shows the degree of agreement found between growth rates calculated in these three ways for the first sowing.

TABLE 27

Nursery experiment 1960-61, 1st sowing. Growth-rates of experimental seedlings relative to those of controls

Estimates based on stem-diameter and on wet-weight increases:

$$r = .70 \text{ (15 DF)}$$

Estimates based on stem-diameter and on dry-weight increases:

$$r = .63 \text{ (12 DF)}$$

Estimates based on wet-weight and dry-weight increases:

$$r = .86 \text{ (12 DF)}$$

Of the three methods of estimation used that based on dry weights is probably the most reliable, but it requires both that some seed should be available for dry-weighing and that the seedlings should be destroyed and cannot therefore be used for a field-planting. That based on wet-weights correlates fairly well with that based on dry-weights, but it is thought to be less reliable as the quantity of mucilage about the bean varies. Estimates based on stem diameters are probably fairly reliable but in the present trial they were recorded only for a small part of the period of the experiment.

Very good performances were obtained from many varieties, especially in the first sowing (November, 1960); thus seedlings from one pod of T12/61 $\times$ Amelonado grew 2.32, 2.54 and 2.20 times as fast as the Amelonado seedlings as judged from stem diameter, wet weight, and dry weight respectively; another pod of this same cross gave values of 2.75, 2.29 and 1.95. However values obtained from different pods of the same cross were not always consistent and a third pod of this same cross gave values of 0.54 and 0.64 on diameters and wet-weights, no seed having been available for dry-weighing. Seeds from this pod were especially small, and poor results were likewise obtained from other pods in which the seeds were very small. It is probable that the seedlings were small at the outset and were further suppressed by being overshadowed by the Amelonado controls.

For future work with this technique it would seem advisable:

1. To pollinate from the type to be investigated onto a tester-variety, which for West Africa should be Amelonado. In this way major differences in bean-size, moisture-content of the beans and the quantity of pulp about the beans might be avoided.
2. Use the same tester-variety, self-pollinated, as the control.
3. As in the present experiment, use equal numbers of seedlings of the 'experimental' and 'control' varieties, intermingled on a grid-system.

STUDIES ON CROP SETTING IN A LARGE BLOCK OF A SELF-INCOMPATIBLE CLONE

Observations have been made in a 5-acre block of the clone E1 at Bunso. The data has been prepared for publication elsewhere, so only a brief summary will be presented here.

The plot is surrounded on three sides by forest, and separated from other cocoa on the fourth side by a dense barrier of 'bush'. Setting in general appears very sparse, but a yield of about 500 lbs. of dry cocoa per acre has been obtained in recent years. There is some evidence that the crop has been relatively greater in that part of the plot nearest to other cocoa.

Studies during 1961 revealed that about 65,000 flowers were produced per tree, and about 8 per cent were pollinated; thus about 5,200 pollinations must have taken place per tree. Sets obtained averaged about 31 per tree, i.e. about 0.6 per cent of pollinations. This rate was so low that it seemed possible that much of this setting may have resulted from failure of the self-incompatibility mechanism, and not, as had previously been presumed, have been due entirely to 'foreign' pollen entering the plot.

The 'bush' barrier separating the plot from other cocoa was cut down early in September, and following this some changes in the pattern of setting were observed. Setting increased most markedly on trees along the line of the main drainage channel, which passes downwards into the other cocoa, and it appeared that there had been an influx of insects passing up the valley and carrying 'foreign' pollen from the other cocoa. This effect extended at least 115 yards into the plot, and possibly 180 yards.

'Cherelle wilt' was estimated at about 43 per cent of sets, which is very low relative to normal values in this area (c.f. McKelvie, A. D. *J. exp. Bot.* II: 413-424, 1960). The data appear to support McKelvie's finding that 'cherelle wilt' is basically a shedding of excess crop, the setting on these trees being less than usual in relation to the crop they are able to bear.

STUDIES ON THE FIRST CLONAL TRIAL

Studies have been made on the data from this trial from planting in 1947 to the end of the 1960-61 season. It is proposed to publish the results elsewhere so only a very brief summary will be presented here. The trial consists of 20 clones planted in six replications of 16-tree plots at 10 ft. $\times$ 10 ft. spacing.

Numbers of pods, pod size, and total yield

The number of pods obtained totalled over the eleven years 1950-51 to 1960-61 ranges from about 700 to over 5,000 per plot,

but the distribution does not depart very far from normal. The general analysis of variance gives a coefficient of variability of 21 per cent. Differences between varieties are very highly significant. The pod-weights of varieties differ very considerably (99 gm. to 165 gm. wet cocoa) and pod-weight is negatively correlated with the number of pods obtained per variety. Pod-weight is not however correlated with the total wet weight obtained from a variety. Estimates of the total yield per variety for the full eleven-year period range from 887 kg. to 2,508 kg. wet cocoa, equivalent to about 3,500 lbs. and 10,000 lbs. of dry cocoa per acre respectively.

Ease of establishment, dry season retention of foliage, and drought tolerance

The effects of a very severe dry season early in 1959 were studied. It proved that varieties most severely defoliated were set back in yield, relative to the others, in the 1959-60 cropping season. It also proved that these varieties were those which had been most difficult to establish in the early years, needing frequent replacements.

Ease of establishment, rate of growth, and yield

There was no relationship between the number of replacements needed per variety and the subsequent rate of growth of the variety, though naturally clones which needed frequent replacements came to consist of generally younger plants, and at a recording of diameters in 1957 they were on the whole smaller. Total yield is related to the diameters in 1957, to the rate of growth up to 1957, and also, though less strongly, to ease of establishment. It is not related to retention of foliage in the 1959 dry season, nor to the set-back in yield in the 1959-60 season, so its relationship to ease of establishment is probably brought about by the influence the latter has on the age and consequent size of the plants.

Pod-size, bean-size, and bean number

The pod-size of a variety is related to the bean-size and also to the number of beans, but the number of beans and their sizes are unrelated.

Pod-disease losses, period of crop production within a season, and breadth of that period

Susceptibility of varieties to pod diseases varies very considerably, discards over a seven-year period ranging from 8 to 28 per cent. The season of crop production of different varieties, as also the breadth of the period of cropping, vary considerably; in the 1958-59 season the central dates for the main-crop of individual varieties varied from the 4th November to the 22nd December, while the standard

deviation of the cropping period ranged from 24 to 34 days. No clear associations between these factors, nor between any one of them and those discussed above, have been established.

Pod-size etc., variation within a season and from plot to plot

Pod-size generally tends to decline over the main-crop period; in the 1958-59 season the average for the trial declined from 138 gm. in September to about 100 gm. in January. Bean-size also declined considerably (3.6 gm. to 3.0 gm., wet) but the number of beans per pod changed relatively little (37 to 34). There is also some evidence of a tendency superimposed on this general trend for the pods to be proportionally smaller during the peak cropping periods of individual varieties.

A number of harvests of one particular variety in the 1957-58 season were studied; a similar reduction in pod-weight and bean-weight over the season was observed. Differences between individual plots of the variety were also confirmed, but it proved that pod-weight was negatively correlated over plots with number of pods, as also was bean-weight. No influence of position (i.e. 'plot') on pod-size etc., independent of its influence on numbers of pods per plot has yet been confirmed.

COMMENCEMENT OF A NEW CYCLE OF BREEDING

Pollinations have been commenced to produce four new series of varieties. Most of the crosses being made are between Amazon and either Amelonado or 'local hybrid' varieties; a few are Amazon $\times$ Amazon. 'Series III', which it is hoped will prove to consist of good general purpose varieties, consists of crosses between a chosen Amelonado and selected individuals from F₂ progenies of Nanay $\times$ Parinari hybrids. Seven such individuals have been selected from F₂ generations of T60 and one from an F₂ of T63. Selection was based on pod-size, bean-size, yield and black-pod losses; some information on fat content has been collected and information on virus reaction (Nanay or Parinari type of symptom) is being collected at Ibadan but unfortunately was not available in time to be incorporated as a selection criterion. 'Series IV' consists of crosses between different Amazon parents or between Amazon and 'local hybrid' varieties, selection of parents having been based primarily on virus tolerance but attention also having been paid to pod-size, bean-size, black-pod losses, etc. A few of these crosses which appear hopeful from the general point of view are to be included in trials with 'Series III', as well as being tested separately in virus tolerance trials. 'Series V' consists entirely of Amazon $\times$ 'local hybrid' crosses, selection having been based primarily on black-pod resis-

tance, though again not ignoring other factors; one of the crosses is thought worthy of inclusion in trials with 'Series III'. 'Series VI', again consisting of Amazon $\times$ 'local hybrid' crosses, involves parents which it is thought may offer some drought resistance.

REPORT ON THE VARIETIES: CHECK LIST: EXPLANATORY NOTES

Following on a report entitled 'New W.A.C.R.I. Varieties, the Present Position' issued in October 1959, a report 'New W.A.C.R.I. Varieties, the Position at October 1961' has been cyclostyled and distributed.

A 'Check list' of W.A.C.R.I. breeding material and varieties has been cyclostyled; this is a detailed document intended mainly for internal use. A set of 'Explanatory notes' has also been prepared, being partially an abbreviation of the 'Check list' and being intended for more general distribution.

THE PERFORMANCE OF AMELONADO COCOA FROM FIVE SOURCES IN GHANA AND NIGERIA (T. H. R. Hall and R. W. Smith)

The 'West African Amelonado' variety appears in general to be very uniform, and evidence at present available suggests that it is derived entirely from plantings on islands in the Gulf of Guinea (San Thome, Fernando Po, etc.), which in turn may have had very limited origins. It is a self-compatible variety, and tends to inbreed. A trial was established in 1950 using seed obtained from some of the oldest and some of the youngest plantings known in Ghana and Nigeria, to determine if vigour had declined due to the generations of inbreeding separating the younger from the older plantings.

Bearing commenced in 1956, and yields for six seasons are shown in Table 28. No significant differences between the five Amelonado sources are apparent; thus there is no evidence of a decline in vigour with additional generations of inbreeding. It is probable though that the material was already considerably inbred before it was introduced to the mainland.

In 1958 a small fertilizer experiment was superimposed on this experiment. There were slight apparent responses to the fertilizers applied (an NPK commercial mixture, proportions 12:24:12, and the NPKMg 'W.A.C.R.I. Mixture', responses 11 and 5 per cent respectively) but these were not significant due to high variability of the cocoa (Coeff. of Variation = 33 per cent).

TABLE 28

Mean annual yield of West African Amelonado Progeny from various sources in West Africa expressed as pounds dry cocoa per acre

Year	Source of seed				
	A	D	C	D	E
1956-57	67	80	82	86	55
1957-58	288	336	215	342	218
1958-59	878	1003	952	1121	973
1959-60	1264	1424	1325	1585	1360
1960-61	1813	2144	1860	1792	1686
1961-62	1130	1593	1295	1231	1198
Total	5440	6580	5729	6155	5490
Mean	907	1097	955	1026	915

- A. Seedling Progeny of Aburi Amelonado of San Thomé origin.
 B. Seedling Progeny of Mampong Amelonado of Fernando Po origin.
 C. Seedling Progeny from Nankese youngest known bearing Amelonado in Ghana.
 D. Seedling Progeny from Ibadan, Nigeria of Fernando Po origin.
 E. Seedling Progeny from Ijebu Ode youngest known bearing Amelonado in Nigeria.

PHYSIOLOGY OF COCOA

(R. G. Lockard and E. J. A. Asomaning)

GREENHOUSE

The completion of the greenhouse was reported in the last annual report. It has now been in use for nearly a year and has proved very satisfactory. All the experiments carried out in the greenhouse up to now have been done in sand-culture, using Amelonado cocoa as the test variety. The results of several of these are reported below.

A few minor changes have been made in the water collection system. An 8,000 gallon steel tank has been erected to give additional water storage capacity. The small portable resin units used originally to purify water have now been replaced with six plastic columns. Four of these are polythene columns, 6" in diameter and 6' tall, containing cation and anion resin alternately. The other two are perspex (clear acrylic) tubing, 6" in diameter and 5' 6" tall, which will be used for mixed resin columns. Clear plastic material has been used to facilitate regeneration of the resins.

Temperatures in the greenhouse still tend to be high. Maximum figures on a clear day at a height of 2 ft. from the floor average 92°F., with 55 per cent relative humidity. This compares with outside temperatures (over grass) of 86°F, and 65 per cent relative humidity.

Cocoa plants grown in pots painted black have shown some leaf

edge scorch presumed to be due to high temperatures in the pots. However, plants grown in pots painted white show less leaf edge scorch and grow at rates far in excess of plants grown elsewhere, either in the field or in potted soils. This is attested to by the data reported in the experiments that follow.

A more detailed report on the construction and function of the greenhouse will be published elsewhere.

TECHNIQUES OF SAND AND NUTRIENT PREPARATION

Sand preparations

The sand used for experiments in the greenhouse has been obtained from the W.A.C.R.I. square mile. The size of sand particles was 0.3–0.8 mm. and 55 per cent of the tap-washed sand falls into this range. This sand has proved to be very pure; of the nutrient elements, only traces of manganese and iron have been detected on total analysis. Sand purification methods for macronutrient and micronutrient deficiency experimentation have been based on the Long Ashton techniques of cold and hot acid washing respectively.

Nutrient solutions

The avoidance of contamination of the substrate is among the more exacting demands of experimental plant nutrition. This is especially true in cases where severe symptoms of nutrient deficiency are to be produced. Generally, the methods of nutrient and sand purification employed have depended largely on the nature and severity of the deficiency symptoms desired. The substrate purification methods used in the following experiments have been adapted chiefly from those described by Hewitt (*Technical Communication No. 22, Bureau of Horticulture, East Malling, 1952*) and Munns and Johnson (*Plant Physiology, 1960, 35: 978–981*). The essential mineral nutrients of interest here have been broadly classified under two categories as follows:

1. **Macronutrients:** These include the elements nitrogen, phosphorus, potassium, calcium and magnesium.
2. **Micronutrients:** These comprise the elements iron, zinc, boron, manganese, copper and molybdenum.

Together with other elements not mentioned above, e.g., sulphur and chlorine, all the components of macro- and micronutrients must be present in balance in the nutrient medium to ensure normal growth.

The macronutrient and micronutrient salts used in the macro-

nutrient deficiency experiments were of 'Analar' grade and reasonably pure, and therefore required no further purification.

The macronutrient salts employed in micronutrient deficiency experiments, even though they may be of 'Analar' grade require to be further purified. The macronutrient purification methods routinely used in this laboratory are as follows:

- (a) Removal of boron and halides by the nitric acid evaporation treatment described by Munns and Johnson (*loc. cit.*).
- (b) Removal of iron, zinc, manganese and copper by the technique of co-precipitation with $\text{Mg}(\text{OH})_2$ also described by Munns and Johnson (*loc. cit.*) has been employed.
- (c) Removal of molybdenum by the method of co-precipitation with CuS described by Hewitt (*loc. cit.*).
- (d) Removal of all micronutrient contamination from a single set of macronutrient stock solutions.

It is clear from the nutrient purification methods mentioned above that a single experiment which aimed at simultaneously studying the comparative effects on growth of each of the micronutrient elements must employ three separate sets of complete macronutrient stock solutions, each of them purified in a different manner. A single complete macronutrient stock solution, prepared by applying each of the methods mentioned in turn, is thus desirable. Such a stock solution has been prepared and a pilot experiment is in progress to study the sequence in which deficiency symptoms of the micronutrients develop and symptoms of multiple micronutrient deficiencies.

COMPOSITION OF COMPLETE NUTRIENT SOLUTIONS

Unless otherwise indicated, the concentrations and composition of essential mineral nutrients in the complete nutrient solutions were as follows:

Nitrogen:	110 ppm (70 ppm as $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ + 40 ppm as NaNO_3)
Phosphorus:	24 ppm as K_2HPO_4
Potassium:	60 ppm as K_2HPO_4
Calcium:	100 ppm as $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$
Magnesium:	40 ppm as $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
Sulphur:	54 ppm mainly as $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
Zinc:	0.50 ppm as $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$
Copper:	0.02 ppm as $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
Boron:	0.50 ppm as H_3BO_3

Manganese: 1 ppm as $\text{MnSO}_5 \cdot 4\text{H}_2\text{O}$
Molybdenum: 0.02 ppm as $(\text{NH}_4)_6 \text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$
Iron: 5 ppm as FeEDTA prepared from $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
and Na_2EDTA .

In the macronutrient experiments deficient cations were replaced by sodium and anions by chloride or sulphate.

The excess levels of copper and iron in the micronutrient experiments were respectively at 0.2 ppm and 50 ppm.

THE EFFECTS OF MACRONUTRIENTS AND VIRUS ON THE GROWTH OF COCOA SEEDLINGS

This was the first experiment undertaken in the greenhouse and it was completed eight months after planting. Control plants were grown in the nutrient solution described above. The deficiency treatments referred to as level 0 in Table 29 were one quarter the control level for phosphorus, potassium, calcium, and magnesium, one half the control level for nitrogen, and one tenth the control level for sulphur. Level 1 was twice the control level for phosphorus and thrice the control level for nitrogen. At the time of the second harvest, 126 days from planting, only magnesium was showing good deficiency symptoms. For this reason the deficient nutrients in the level 0 treatments were thereafter reduced to zero.

All the nutrient treatments were repeated on plants infected with swollen shoot virus of the New Juaben strain (see Table 29). Seeds were infected by the usual method of feeding infected mealybugs on the embryo after one cotyledon was removed.

Plants were thinned to one plant per pot and were harvested four times at two monthly intervals. Each treatment was replicated three times for each harvest, making a total of 216 pots. Only the more pertinent data will be discussed here. A more detailed report will be published elsewhere.

Nutrient deficiency symptoms

In general the deficiency symptoms obtained in this experiment correspond with those already published for cocoa. However, the phosphorus and potassium deficiency symptoms were more like those of Lockard, R. G., Vamathevan, P., and Thamboo, S. (*Minist. Agric. Fed. Malaya, Bull.* 107, 1959) than those reported by Maskell, E. J., Evans, H., and Murray, D. B. (*Imp. Coll. Trop. Agric. Rep. Cacao Res.*, 1945-51) or by Loué, A. (*Institut Français du Café et du Cacao, Bull.* No. 1, 1961). This was particularly true of the early stages of phosphorus deficiency where the yellow and brown areas invariably occurred on only one half of the leaf. Another symptom

not previously reported was a wavy margin on the tip half of young leaves suffering from phosphorus deficiency. Some of the oldest leaves on the potassium deficient plants showed leaf edge scorch symptoms like those reported by Maskell, *et al.* (*loc. cit.*), but others showed light green interveinal areas with necrotic patches appearing first at the basal edges of the leaf. In medium-aged potassium deficient leaves symptoms first occurred as yellow areas along the midrib, usually starting near the base of the leaf and advancing along the midrib towards the tip. Necrosis occurred first in the middle of the leaf along each side of the midrib. The necrotic areas then extended out towards the edge of the leaf, as described by Lockard, R. G. *et al.* (*loc. cit.*) and in many cases leaves which were virtually all brown had thin green margins along the edges of the laminae near the tip.

Calcium deficiency symptoms were similar to those shown by Loué as advanced symptoms. However, the more severely deficient leaves curled along the edges and the whole leaf cupped into a boat shape.

Sulphur deficiency symptoms were not obtained in this experiment because in addition to the treatment, sulphur was supplied at 5.7 ppm in the ferrous sulphate used to prepare the chelated iron (FeEDTA).

Nutrient and virus effects on growth

The effect of treatments on plant dry weight can be seen in Table 29. All nutrient treatments significantly reduced the dry weights of leaves, stems, and roots. Treatment Ca₀ had the most severe effect and P₁ the least effect on dry weight.

There was an interaction effect on leaf dry weight between treatments Ca₀ and virus, in which the reduction in weight was less in the plus virus than in the minus virus treatment. This is the general trend of all treatments, presumably because the virus infected plants are smaller and have a lower nutrient requirement.

The overall effect of virus was to reduce plant dry weight by 57 per cent. However, when nutrient deficiencies were absent virus reduced plant dry weight by 43 per cent.

Leaf area at the fourth harvest was significantly reduced by all treatments, including the virus treatment.

The percentage moisture in the leaves was significantly reduced by all nutrient treatments except N₁. Several nutrient treatments (N₀, K₀, Ca₀) significantly reduced the percentage moisture in the stems, but no nutrient treatments had any significant effect on percentage moisture in the roots. On the other hand, the virus significantly reduced percentage moisture only in the roots.

The stem height at the fourth harvest was significantly reduced by

TABLE 29

The effects of macronutrients and swollen shoot virus on dry weight (gm.) of cocoa seedlings (4th harvest) (a)

Treatment	Leaves		Stems		Roots		Total plant	
	—Virus	+Virus	—Virus	+Virus	—Virus	+Virus	—Virus	+Virus
N ₀	36.9	6.5	33.5	5.6	20.3	6.4	18.5	54.6***
N ₁	69.4	16.5	29.7	7.7	12.9	6.6	30.9	71.4***
P ₀	46.0	14.3	41.1	12.1	15.1	9.0	35.4	68.8***
P ₁	59.3	23.7	33.6	12.0	19.0	10.5	46.3	79.1***
K ₀	50.1	23.1	35.9	13.5	18.6	10.3	46.8	75.7***
Ca ₀	18.0	10.1	16.1	4.6	9.1	4.0	18.7	31.0***
Mg ₀	46.3	19.4	30.4	11.4	19.1	10.5	41.3	68.5***
S ₀	44.9	23.9	28.0	10.7	15.9	8.7	43.3	66.0***
Control	86.8	50.1	58.4	33.8	25.4	18.0	101.9	136.2
Mean	50.8	20.9***	34.1	12.4***	17.3	9.4***	42.6***	72.4

(a) Means of three plants per treatment

Asterisks indicate significant difference from the control and between plus and minus virus

** P = 1 per cent level

*** P = 0.1 per cent level

all nutrient treatments, and by virus. The mean height of control plants at the fourth harvest, 8 months from planting, was 173 cm.

The chemical analyses showed that, at the fourth harvest, all zero treatments had significantly reduced the level of the respective nutrient in the leaves and stem but not always in the roots. The treatment N₁ significantly increased the level of nitrogen in all plant parts when compared to the control. However, the treatment P₁ did not significantly increase the phosphorus level in any plant part when compared to the control.

The effect of the virus on the nutrient constituents of the plant was variable. It significantly increased the level of nitrogen and potassium in the leaves and stems and potassium in the roots. On the other hand, it significantly decreased the level of calcium and magnesium in the leaves and tended (significant for calcium) to increase it in the stems.

LEAF EDGE SCORCH

In the macronutrient X virus experiment it was noticed that some treatments had more leaf edge scorch than others. This scorch is similar to the symptoms of potassium or calcium deficiency on older cocoa leaves and occurs fairly commonly in Ghana on trees which are not well shaded. It is also a very common symptom in cocoa nurseries where shade is inadequate.

The appearance of leaf edge scorch on these unshaded plants was, therefore, not surprising but the differential effect due to treatment was interesting.

A score of leaf edge scorch, ranging from 1 to 5 and increasing with severity, was taken on these plants on two occasions. The results can be seen in Table 30.

TABLE 30
*Effect of different nutrient treatments on the
leaf edge scorch of cocoa seedlings*

<i>Age of plants</i>	<i>Control</i>	<i>N₀</i>	<i>N₁</i>	<i>P₀</i>	<i>P₁</i>	<i>K₀</i>	<i>Ca₀</i>	<i>Mg₀</i>	<i>S₀</i>	<i>Mean</i>
90 days	10	0*	55***	10	11	17	45***	44***	7	22.1
124 days	16	0	54**	17	20	33	51*	51*	6	27.6

Plants scored from 1 to 5 figures are the sum of 18 plants

Asterisks indicate significant difference from the control

* P = 5 per cent level

** P = 1 per cent level

*** P = 0.1 per cent level

The treatments contributing most to leaf edge scorch were high nitrogen (N_1), low calcium (Ca_0), and low magnesium (Mg_0). There was no scorching in the low nitrogen (N_0) treatment. It is not possible to determine from these data whether the scorch is due to high N:Ca or N:Mg ratio or whether the ions act independently.

In our opinion the scorch is due to high NO_3 accumulation in the leaves. This can be brought about by a supply of excess nitrogen but a deficiency of calcium or magnesium can also contribute to it, as shown by Murray, D. B. (*Imp. Coll. Trop. Agric. Rep. Cacao Res.*, 1955-56: p. 21-22) and Lockard *et al.* (*loc. cit.*).

It would therefore appear from Table 30 that the nitrogen concentration (110 ppm) in the control nutrient solution may be too high. This problem is being investigated further.

THE EFFECTS OF MICRONUTRIENTS AND COCOA SWOLLEN SHOOT VIRUS ON THE GROWTH OF COCOA SEEDLINGS

Some micronutrient deficiency symptoms have at times been confused with symptoms of virus disease. Greenwood, M. and Hayfron, R. J. (*Empire J. Expt. Agric.*, 19: p. 78 (1951)) cite instances in West Africa of zinc deficiency symptoms being repeatedly tendered as evidence of swollen shoot disease, and the present writers have also noted a tendency on the part of inexperienced field staff to confuse experimentally produced symptoms of zinc, iron, manganese and copper deficiency with virus disease.

Thus in July, 1961, a study of possible virus-micronutrient interactions was included in our general nutritional investigations in sand culture.

Each of the following micronutrient treatments was applied to virus-infected and virus-free seedlings:

1. Complete nutrient (control)
2. Complete nutrient minus manganese
3. Complete nutrient minus boron
4. Complete nutrient minus zinc
5. Complete nutrient minus molybdenum
6. Complete nutrient minus iron
7. Complete nutrient minus copper
8. Complete nutrient plus excess copper (i.e. 0.2 ppm. copper)
9. Complete nutrient plus excess iron (i.e. 50 ppm. iron)

The New Juaben strain of CSSV was used.

The experiment was planned to last for 12 months, plants being harvested at three-monthly intervals.

TABLE 31

The effects of micronutrients and swollen shoot virus on fresh and dry weights of cocoa seedlings

Nutrient Treatment	Months after planting	Total fresh weights (gm.): sum of three plants				Total dry weight (gm.): sum of three plants			
		No Virus	+ Virus	Nutrient effects Mean + and—	Virus × Nutrient Interaction	No Virus	+ Virus	Nutrient effects Mean + and—	Virus × Nutrient Interaction
Complete	3	45.6	26.0	35.8	—	11.5	7.3	9.4	—
— Manganese	6	448.7	126.2	287.5	—	136.9	33.9	85.4	—
— Boron (1)	6	51.1	14.0	32.6NS	NS	13.8	3.3	8.6NS	NS
— Zinc (1)	6	251.3	44.1	147.7*	NS	64.3	10.8	37.6*	NS
— Molybdenum	6	32.1	17.5	24.8NS	NS	8.5	4.3	6.4NS	NS
— Iron (1)	6	115.9	23.1	69.5**	NS	25.9	5.8	15.9*	*
— Copper	6	30.0	22.9	26.5NS	NS	7.6	6.5	7.1NS	NS
— High Iron	6	118.6	27.3	73.0**	NS	30.5	5.8	18.2*	*
— Manganese	6	62.5	24.5	43.5NS	NS	14.4	6.6	10.5NS	NS
— Iron (1)	6	634.2	199.4	416.8*	NS	180.8	54.0	117.4*	NS
— High Iron	6	38.9	20.5	29.7NS	NS	8.8	4.8	6.8NS	NS
— Copper	6	86.6	111.9(2)	99.7**	*	22.3	23.3	22.8**	**
— High Iron	6	50.3	42.1	46.2NS	NS	11.3	11.0	11.2NS	NS
— Copper	6	327.6	94.2	210.9NS	NS	80.3	25.7	53.0NS	NS
— High Copper	6	41.4	27.0	34.2NS	NS	11.0	7.3	9.2NS	NS
— High Copper	6	147.2	68.1	107.7**	NS	36.0	17.2	26.6**	*
— High Copper	6	46.7	30.6	38.7NS	NS	9.5	8.3	8.9NS	NS
— High Copper	6	398.2	286.2	342.4NS	NS	121.0	81.1	101.1NS	NS
— High Copper	6	44.3	25.0***	34.7	—	10.7	6.6***	8.7	—
— High Copper	6	307.7	109.0***	208.4	—	76.8	28.6***	52.7	—

(1) Plants were deliberately contaminated for 2 weeks after the 3rd month with the following concentrations of the deficient element: B, 0.005 ppm; Zn, 0.005 ppm; Fe, 0.1 ppm.

Asterisks indicate significant differences at the following levels:

* P = 5 per cent; ** P = 1 per cent; *** P = 0.1 per cent;

NS = Not significant

(2) One plant in this treatment was not properly infected and seemed excessively contaminated thereby apparently negating the virus effect

The sequence of deficiency symptom development

Iron deficiency symptoms were the first to appear followed by zinc, boron, manganese and copper in that order.

Symptoms of these deficiencies were similar to those previously described for cocoa by Evans, H. and Murray, D. B. (*A Report on Cacao Research*, 1945-1951, p. 66), and Lockard *et al.* (*loc. cit.*). Prominent stem swellings developed on copper deficient plants (cf. Lockard *et al.*).

Up to the end of the period under review no clear symptoms of molybdenum deficiency had appeared. However, plants having the treatment Mo₀ showed an unusually high degree of leaf-edge scorch. Deficiency symptoms appeared more slowly in virus-infected plants but were similar, when fully developed, to those shown by non-infected plants. Certain stages of manganese and copper deficiency symptoms were found distantly to resemble symptoms of virus infection; the similarities could confuse an inexperienced assistant.

Nutrient and virus effects on growth

Fresh and dry weight data up to six months are summarized in Table 31.

Irrespective of nutrient treatment, virus infection significantly reduced growth ($P = 0.1\%$). Deficiencies of manganese, boron, zinc, iron and copper also had significantly reduced the growth of both infected and non-infected seedlings six months after planting. Analysis of the dry weight data showed an interaction between virus, and deficiencies of boron, zinc, iron and copper respectively. These interactions were found to be very closely correlated with the severity of the nutrient deficiency symptoms.

Up to the sixth month, molybdenum deficient plants appeared to be doing as well as or even better than the controls. It is considered that plants in this treatment might have been contaminated. The position is therefore being re-investigated with regard to molybdenum deficiency.

The excess levels of iron and copper have so far shown no interaction with virus.

Two more harvests remain in this experiment and these will be taken 9 and 12 months after planting. Detailed analyses will be made with respect to the responses of the separate plant parts (roots, stems and leaves) to the various treatments described. The two harvests reported here have shown that virus infection has had no effect on the percentage moisture content of the plants.

COPPER SPRAY TRIAL

A copper spray trial was initiated in February 1960, with a view to testing the nutrient effects of copper in a copper fungicide. This experiment was planned as a result of the work reported by Tollenaar, D. (*Tropical Agric., Trin.* 36: 177-188, 1959). In this paper he reported an increase in cocoa production resulting from foliar applications of copper as an additional effect to witch's broom disease control.

The spray trial was superimposed on a spacing trial which has eight different spacings in seven blocks. Block I was sprayed with 0.5 per cent copper sulphate solution (1,270 ppm. of copper), Block IV was sprayed with tap water and Block VII was sprayed with 1.0 per cent 'Perenox' (5000 ppm. of copper). The sprays were applied at four-weekly intervals for two years.

The two years yield data (in pod numbers) were corrected by covariance on two years pre-treatment data. The results were as follows:

	I	IV	VII
Number of healthy pods per plot	Cu SO ₄ 4185	Water 5207	Perenox 5693

Although neither copper spray was significantly different from the control they were significantly different from each other ($P = .05$).

The data indicate that the copper sulphate spray was toxic to the plants. It would be more readily available both on the leaves and in the soil than the copper in 'Perenox'. There would appear to be some stimulating effect of 'Perenox' in addition to its effect on black-pod disease. Black-pod affected less than 2 per cent of the crop whereas 'Perenox' increased the yield over the water control by 9 per cent. Whether the difference was due to its effect as a nutrient or to its fungicidal properties is unknown.

As the copper sulphate spray was apparently toxic to the plants, it has not been established whether copper as a nutrient will increase cocoa yield.

COMPARISON BETWEEN THE GROWTH RATES OF HALF BEAN AND FULL BEAN COCOA SEEDLINGS

Since most virus infected seedlings used for experimental purposes are raised from half beans, it was felt desirable to study whether the growth of half bean seedlings was permanently retarded. The plants were raised from seed in sand culture and were supplied each day with complete nutrient solutions. Table 32 shows the relationships between fresh and dry weights of half and full beans at the time of planting.

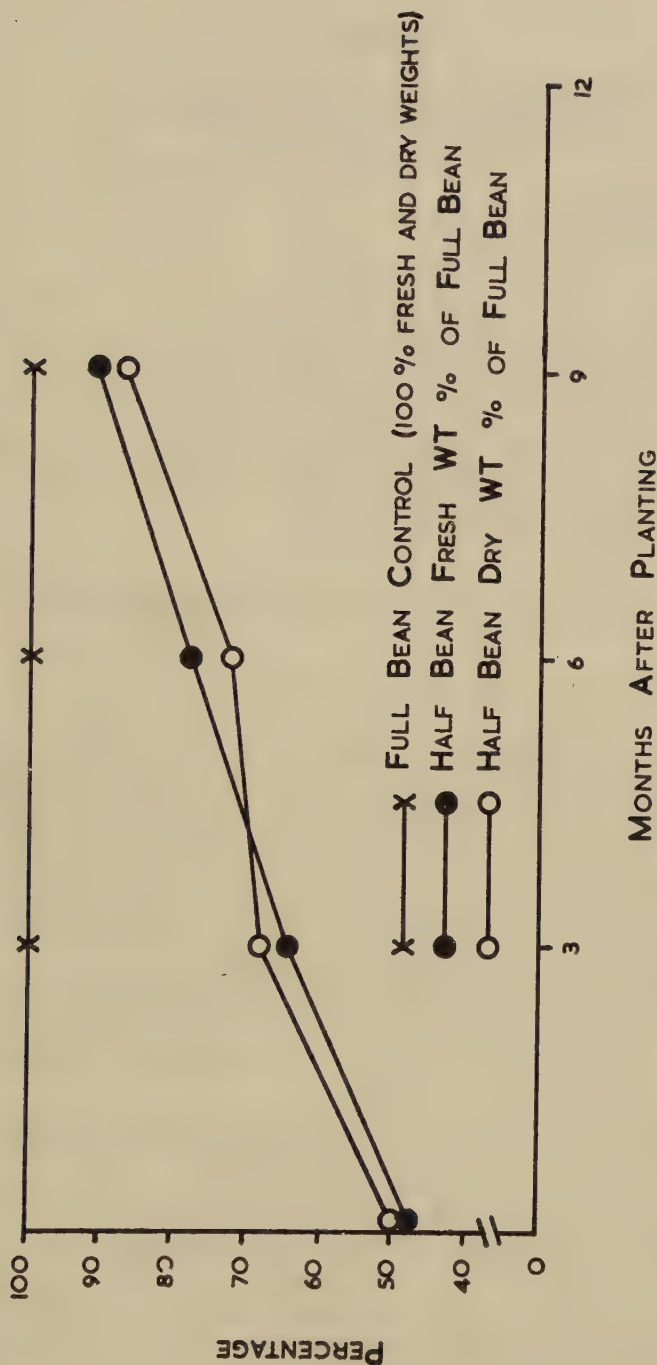


FIGURE 1. Relationship between the growth of full and half bean seedlings

TABLE 32

Relationship between fresh and dry weights of half and full beans at the time of planting

	<i>Fresh weight</i>	<i>Dry weight</i>
Half bean	0.85	0.55
Full bean	1.73	1.133
Half bean/Full bean %	49.0	48.5

The results of this study are summarized in Fig. 1 in which the fresh and dry weights of half bean seedlings are expressed respectively as percentages of the fresh and dry weights of the full bean controls.

Fig. 1 shows that the initial differences in weight between half and full beans are not maintained. There is a progressive narrowing of the gap between the two types of seedlings and it is anticipated that at the final harvest eleven months after planting, there will be no significant differences between them.

A COMPARISON OF GROWTH OF COCOA SEEDLINGS INFECTED WITH FIVE DIFFERENT VIRUS ISOLATES

There have been differences of opinion as to how severely the different virus isolates of swollen shoot affect plant growth. Under field conditions, with varying nutrient status, and varying degrees of insect attack and virus infection, it has been difficult to make accurate comparisons. An experiment was therefore set up in the greenhouse in which seeds were infected by the usual method of feeding infected mealybugs on half beans. Five virus isolates plus a control were replicated four times. The beans were planted in sand in cement pots (size 12" × 12" × 18") and thinned to four plants per pot. All plants were given the control nutrient solution.

One plant was taken from each pot at three-month intervals. Up to the end of the period under review, two harvests had been taken. The dry weights of leaves, stems, roots and total plant at the first two harvests can be seen in Table 33.

The first three produce leaf symptoms and stem swellings. Bisa produces only stem swellings and Kpeve only leaf symptoms.

Bisa produced only one stem swelling and Kpeve produced leaf symptoms only after nine months. However, as there was an effect on growth it is assumed that all plants were infected.

Under these conditions, the virus strains New Juaben and Bosomuosu severely reduced plant dry weight. Dawa was the least severe and Bisa and Kpeve were intermediate. The two most severe strains reduced the leaf and stem weights to a much greater degree than they did root weight.

TABLE 33

*The effect of different virus isolates of cocoa
swollen shoot disease on the dry weight of plants
Plant dry weight (gm.) (^a)*

<i>Virus</i>	<i>Harvest</i>	<i>Leaves</i>	<i>Stem</i>	<i>Root</i>	<i>Total plant</i>
Dawa	1	2.8	0.8	1.0	4.8
	2	33.6***	16.2*	7.6	57.4
New Juaben	1	1.5**	0.3**	0.7*	2.5***
	2	5.5***	2.9***	3.4*	11.8***
Bosomuosu	1	1.4**	0.4**	0.8	2.6**
	2	4.0***	2.0***	2.9**	9.8***
Bisa	1	1.6**	0.5	0.9	3.0**
	2	32.2***	15.7**	7.1	55.0
Kpeve	1	2.4	0.7	0.7*	3.8
	2	25.3***	12.0***	5.1	42.4**
<i>Control</i>	1	3.3	0.7	1.0	4.9
	2	40.4	18.0	7.6	66.0

(^a) Means of four plants per treatment/harvest

Asterisks indicate significant difference from the control

* P = 5 per cent level

** P = 1 per cent level

*** P = 0.1 per cent level

Only New Juaben and Bosomuosu significantly reduced leaf area at the second harvest and the same was true for stem height. At this time the control plants had an average leaf area of 52.3 dm.² and a stem height of 109 cm.

These preliminary data indicate that only a small reduction in growth may result from infections from Dawa, Bisa and Kpeve strains of virus, provided the plants are grown under good conditions. However, the New Juaben and Bosomuosu strain can be expected to give substantial reductions in growth even under good conditions.

SOIL FERTILITY, COVER CROPS, IRRIGATION AND SHADE

THE EFFECT OF MAJOR NUTRIENTS (R. W. Smith and G. S. Akrofi)

Factorial fertilizer experiments

The 1961-62 yields from the factorial experiments are shown in Table 34. All yields are quoted in pounds of dry cocoa per acre assuming a conversion factor of twelve pods to one pound of dry

cocoa. Significant increases in yield have followed applications of triple superphosphate. There have been no increases in yield following applications of the other major nutrients, nitrogen, potassium and magnesium. Interactions between the main effect have not been significant. The yields from the experiments at Akaa, Bienne, Kwadaso and Pankese have been adjusted by covariance analyses using pre-treatment yields as independent variates.

TABLE 34
Factorial fertilizer experiments: estimated yields
(lb./acre) 1961-62

	Bunso	Bunso	Apedwa	WACRI	Akaa	Bienne	Kwadaso	Pankese
	1006	18c	1080	G5				
Without N	1438	684	1027	1012	374	579	321	371
With N	1484	624	942	1016	372	474	341	387
Without P	1447	640	863	886	282	579	321	388
With P	1485	668	1106***	1142***	417***	708***	428*	379
Without K	1423	659	979	1036				
With K	1509	649	990	992				
Without Mg		634	939	1019				
With Mg		674	1030	1009				

*, *** = Significant at $P = 0.05$, and 0.001 respectively

Rates of major nutrients

In Ashanti four experiments are designed to compare applications of forty and eighty pounds of P_2O_5 per acre per year. Provision is made for the inclusion of a third rate, its level depending upon the initial results. In no case has there been a significant difference between the two rates, but in several cases either one or both rates have increased the yield. The results are presented in Table 35.

At Tafo, an experiment (G1) began in 1959, to compare the effects of two rates of each of the major nutrients, nitrogen, phosphorus, potassium and magnesium. Effects produced in the first two years were not shown to be significant due to the high variability of the cocoa and the small replication and large plot size. In the current year, the plots have been divided into four sub-plots for recording purposes. The only significant increases in yield were produced by basal dressings including fifty pounds of P_2O_5 per acre in the rates of nitrogen, potassium and magnesium experiments, and by one hundred pounds of P_2O_5 in the rates of phosphorus experiment. Fifty pounds of P_2O_5 in the latter experiment did not increase the yield.

TABLE 35
Rates of phosphate - 1961-62
Yields in number of pods per plot (lbs. dry cocoa per acre
in brackets) (1)

Site	Control	Treatment		
		NKMg	+40 lb. P ₂ O ₅	+80 lb. P ₂ O ₅
Dampong	106.4 (241)	123.4 (280)	182.4 (414)*	187.5 (425)*
Yawnso	358.0 (812)	425.8 (966)	507.8 (1152)	499.6 (1134)
Poano	220.6 (501)	229.5 (521)	241.2 (547)	318.3 (722)***
Mabang	302.6 (687)	203.4 (462)	365.4 (829)	322.7 (732)
Mean	246.9 (560)	245.5 (557)	324.2 (736)	332.0 (753)

(1) Adjusted by an analysis of covariance using two years pre-treatment yields as the independent variate, and 1961-62 as the dependent variate
 *, *** = Significant at P = 0.05 and 0.001 respectively

Amelonado shade, fertilizer and irrigation experiment (K1)

The 1961-62 results follow a similar pattern to those of previous seasons, although a poor crop year has lowered the level of production in common with many experiments at W.A.C.R.I. It is now clear that the yield of the unshaded cocoa without fertilizer is falling relative to the other treatments. This effect has been expected, and is due to the increased removal of nutrients from the soil resulting from the high yields obtained after removing the limiting factor of heavy over-head shade.

The low yields at W.A.C.R.I. this season were caused by the unusual dry period at the beginning of the season. This dry spell limited flower production. Normal flower production was however maintained on the irrigated plots of this experiment, and has been reflected in a large yield response to the treatment. The results are given in Tables 36 and 37.

TABLE 36
Yields from the shade and fertilizer experiment
(lb. dry cocoa per acre)

	1957-8	1958-9	1959-60	1960-61 (1)	1961-62 (1)
Shade, no fertilizer	586	958	756	702	494
Shade, with fertilizer	849	1,211	906	969	679
No shade, no fertilizer	1,100	2,348	2,187	2,448	1,516
No shade, with fertilizer	1,602	3,091	3,088	3,474	2,435

(1) One-third of the experiment received irrigation in 1960-61 and 1961-62. These figures have been adjusted to represent the expected overall yield if irrigation had not been applied, and are directly comparable to the results of earlier years

TABLE 37

Yield following shade removal, addition to fertilizer, and irrigation (expressed as per cent of control plot yield)

		1957-58	1958-59	1959-60	1960-61	1961-62
Shade removal effects	With fertilizer	189	255	341	359	359
	Without fertilizer	188	245	289	349	307
Fertilizer application effects	With shade	145	126	120	138	137
	Without shade	146	132	141	142	161
Combined effects of shade removal and fertilizer application		273	323	408	495	493
Irrigation (1) effects	Shade + fertilizer	—	—	—	119	133
	Shade without fertilizer	—	—	—	121	151
	No shade + fertilizer	—	—	—	109	126
	No shade without fertilizer	—	—	—	122	152
Combined effects of shade removal, fertilizer application and irrigation		—	—	—	539	712

(1) Percentages based on adjusted means (pods/plot) following an analysis of covariance using pre-irrigation yields as the independent variate

Amazon shade and fertilizer experiment (K2, 01)

The thirty-two acres of clear felled land, uniformly planted in June, 1959, with Amazon cocoa at ten feet spacing, and shaded by *Terminalia ivorensis* at twenty feet spacing, has been laid out as a 3×3^3 shade and fertilizer trial. The routine fertilizer application was applied to all plots in April 1961. No further fertilizers will be applied until the fertilizer treatments commence in April 1963. Thinning of the *T. ivorensis* has commenced, and will continue over the next two years until three shade treatments are attained. These will be heavy shade (20×20), light shade (40×40), and no shade. These main plots will be large and replicated four times. Each main plot will be 'split' to incorporate the 27 fertilizer combinations of a 3^3 NPK factorial. The sub-plot size will be 20 trees. Records of stem diameters were recorded in June 1961. There were no differences between the future fertilizer treatments, but a significant difference ($P = 0.05$) was apparent between the future shade treatments. This observation was confirmed by the yield data, although not significant because of the greater variability of the early yield. The coefficient of variation between the sub-plot is 10.26 per cent when based on stem diameters and 57.75 per cent when based on the 1961-62 yield.

It has been decided to modify the original randomization of the main plots in order to get rid of the difference between the future shade treatments. This will be done by interchanging the no shade and light shade treatments in replication three.

The mean yield for 1961-62, the third year after planting, was Block 1: 143; Block 2: 143; Block 3: 190; and Block 4: 191 pounds of dry cocoa per acre.

The cocoa trees are beginning to form a canopy over the soil, with a consequent reduction in the amount of ground vegetation.

Residual effects of fertilizers

The application of eighty pounds of P_2O_5 per acre in each of two consecutive years has not produced a significantly greater increase in yield than has a single application in the first year alone. Both treatments have increased the yield significantly at two sites, but not at the other two. The results are presented in Table 38.

The NP and the KMg (Ca) treatments on the 2^2 factorial experiment at six sites in Ashanti were discontinued. There was no residual differences remaining in the first year following this discontinuation. At the same time a 2^2 NP factorial was superimposed on the previous treatments. A response has been obtained to applications of triple superphosphate in the first year, but not to urea. There was no significant interaction between the N and P treatments nor between the old and new treatments.

TABLE 38

Yields (Mean of 1960-61 and 1961-62 season) in lbs. of dry cocoa per acre per year, from Residual Effects of Phosphorus Experiment

<i>Treatment</i>	<i>Site</i>		<i>Site</i>		<i>Mean</i>
	<i>Brosankro</i>	<i>Ahwerewa</i>	<i>Eduam</i>	<i>Hwidiem</i>	
NKMg both years	1014	393	787	1361	889
NKMg both years with 80 lbs. P_2O_5 each year	1219*	558*	882	1289	987
NKMg both years with 80 lbs. P_2O_5 first year only	1194*	577*	948	1351	1017

* Significant ($P = .05$) increase over NKMg alone

There was no significant difference between the two phosphorus treatments at any site

The use of fertilizers at planting time

Experiment D11 compared the use of one ounce of NPK (12:24:12) mixture applied in the planting hole and on the surface at time of planting. These treatments, together with a control, were applied to Amelonado, Amazon and Hybrid cocoas in June 1961. The cocoa

was planted at five feet spacing, and thinned when six months old along one diagonal. The trees removed were used to assess the treatment effects. The second diagonal was removed when the trees were nine months old, and the trees similarly used. There has been no significant effect of the treatments on any of the varieties, as measured by heights, stem diameters, leaf number, or wet weight of the trees. The results are given in Table 39.

In view of this negative result a similar experiment is planned for the 1962 routine planting.

TABLE 39
Effects of fertilizer applications at planting time
Data (per tree) at six months after planting

<i>Treatment</i>	<i>Height (in.)</i>	<i>Stem diameter (cm.)</i>	<i>Number of leaves</i>	<i>Total wet weight (gm.)</i>
No fertilizer	118	1.36	27.3	237.9
1 oz. NPK (12: 24: 12) in planting hole	107	1.26	20.8	177.9
1 oz. NPK (12: 24: 12) on surface at planting time	121	1.33	24.8	218.3

COVER CROPS AND MULCHES

The effect of cover crops and mulches on the establishment and yield of cocoa has been studied in Experiment A6. Cocoa has been used as an indicator to assess the value of various cover crops and mulches as soil protectors in Experiment H5. Cunningham, R.K. and Smith, R. W. (*Trop. Agriculture, Trin.* **38**: 13-22, 1961). Further results from these experiments are presented here. The effects of the cover crops used in A6 continue to be reflected in the yields of the cocoa, although the treatments finished in 1958. The cocoa established without competition from any ground cover, i.e. with elephant grass mulch or bare soil, has significantly out-yielded all the other treatments ($P = 0.001$). There is no difference between the other treatments. The growth of the cocoa in H5 and the yield in the 1960-61 season followed a similar pattern. In 1961-62, however, the yield of the cocoa established on soil previously exposed for one year and thereafter maintained weed free, has fallen below that of all other treatments, even the natural regeneration where the competition has been most severe. These results are shown in Table 40.

It is clear that competition from weeds or cover crops is one of the most serious limiting factors in the establishment of cocoa. Establish-

ment on previously exposed and degraded soils is satisfactory, but the cocoa suffers from the lack of good soil structure and nutrients when once established.

The effects of potassium deficiency in A6 as reported in the 1960-61 annual report, continued during the present season. The provision of artificial shade and irrigation during the dry season did not prevent the development of symptoms on the new flushes. The symptoms were, however, reduced by application of a foliar spray of potassium sulphate.

TABLE 40
*Growth and early yield of cocoa established on soils
exposed the previous year or under cover crop and
mulch treatments*

Treatment	Stem diameter (cms.) one year after planting	Yield (pods per plot)	
		1960-61	1961-62
Bare soil	1.77	3.8	26.9
Natural regeneration	1.40	1.1	27.5
Guatemala grass mulch	1.98	5.0	52.6
Guatemala grass cover	1.72	2.6	48.1
Crotalaria striata	2.07	5.6	45.3
Stylosanthes gracilis	1.85	8.8	41.3
Zebrina pendula	1.80	7.9	54.8
Sig. Diff. at $P = 0.05$	0.21	—	22.5

SOIL CHEMISTRY (D. K. Acquaye)

Soil phosphorus and cocoa yield response studies

The investigations on phosphorus in soils from the 2² NP:KMg Ca factorial trials at Domiabra, Obuasi, Antoakrom and Brofoyedru were continued. The correlation coefficients between yield and the various soil data on the 0-2" samples are given in Table 41.

TABLE 41
*Correlation coefficients (r) between yield and
soil analysis data*

	Yield	
	1960-61 season	4 years' total
Available P (ppm)	0.424	0.249
0.2N H ₂ SO ₄ extractable P (ppm)	0.408	0.567*
Organic C (per cent)	0.583*	0.750**
Organic P (ppm)	0.732**	0.925***
Total N	0.648**	0.940***

Levels of significance indicated as follows:

* = 5 per cent; ** = 1 per cent; *** = 0.1 per cent

As the results of these studies are being prepared for publication, it will suffice to mention them summarily here.

The application of NP alone resulted in a decrease in the exchangeable bases while the percentage base saturation increased in the KMg(Ca) and NPKMg(Ca) treatments due to the build-up of exchangeable Mg and Ca from the dolomitic limestone applied. The percentage carbon values of the 0-2" samples at Antoakrom, Brofoyedru and Domiabra (where there was response to NP) were higher than at Obuasi (where there was no response), and the organic phosphorus content increased in the former soils but tended to decrease in the latter soil as a result of NP application. The effect of the organic matter shown by the correlation appears to be due either to the retention of more of the applied phosphate in available form or to the increase in mineralization of organic phosphorus. The latter explanation seems to be more plausible since the correlation between yield and the available phosphorus was not quite significant whereas the organic phosphorus, organic carbon and total nitrogen were highly significantly correlated to the yield. Furthermore, the organic phosphorus was correlated to the organic carbon ($r = 0.630^{***}$) and total nitrogen ($r = 0.882^{***}$) and the 0.2N H₂SO₄ extractable phosphorus was correlated to the organic carbon ($r = 0.613^*$) and almost correlated to the organic phosphorus ($r = 0.457$).

Soil organic phosphorus studies

The importance of the organic phosphorus in the 0-2" samples of soils of the above 2² NP: KMg Ca factorial experiment was studied in laboratory incubation experiments (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61). Organic phosphorus was found to range from 46.0 to 69.5 per cent of the total phosphorus in these soils and was correlated to the percentage total nitrogen, total phosphorus, organic carbon and pH.

Incubation of the soils at 50 per cent of their water holding capacities and a temperature of 27°C for periods of 14, 28, 42, 56 and 70 days resulted in the average mineralization of organic phosphorus equivalent to 4.0, 13.6, 38.2, 50.0 and 54.0 lbs. P/acre of soil respectively. Mineralization was higher at 40°C and higher still at 50°C. The percentage of organic phosphorus mineralized was generally higher in the plots which received the NP treatment; and laboratory applications of nitrogen and phosphorus separately to the soils before incubation resulted in greater mineralization than in their absence. The effect of nitrogen and phosphorus together was greater than nitrogen alone but only in a few cases was it greater than that of phosphorus alone. The effect of nitrogen and phosphorus was not additive.

It is concluded that although the organic phosphorus increased in the NP treated plots, increased mineralization occurred concurrently, and the effect of nitrogen and phosphorus applications in increasing the mineralization of the soil organic phosphorus during laboratory incubation explained the high correlation found between cocoa yield response and organic phosphorus content of the top soil. Phosphorus and nitrogen fertilization appears not only to improve the phosphorus and nitrogen contents of the litter, and thus its mineralization, but also to enhance the mineralization of the organic matter already present in the soil.

Fertilizers and litter

Soil sampling on this experiment has continued. There appears to be a marked seasonal effect on the exchangeable K and nitrification in the soil; the effect of the previous shade treatment is still great. The results will be fully discussed at the end of the experiment.

A comparative study of forest and cocoa soils at W.A.C.R.I.

The investigations on the various soil series under forest (or secondary forest) and under cocoa to assess some of the chemical and biological changes reported last year have continued. Seasonal effects on exchangeable potassium and differences in nitrification are being followed. The results will be summarized at the completion of the experiments.

Pot experiment

The pot experiment mentioned a year ago, in which the techniques of controlled shade, side protection, and continuous watering from beneath, developed by Cunningham and Burridge, were employed to test the effects of two sources of nitrogen and phosphorus on the growth and uptake of soil nutrients has been harvested.

The experiment was of a factorial design involving:

(G): 3 soil types from Hwidiem, Mabang and Yawnso.

(N): 2 sources of nitrogen: sulphate of ammonia and urea.

(n): 4 levels of nitrogen: nil, 57, 114 and 288 lb. N/acre of soil.

(P): 2 sources of phosphorus: rock and triple superphosphate.

and (p): 3 levels of phosphorus: nil, 286 and 857 lb. P_2O_5 /acre of soil.

All the treatments with one replication were randomized in 144 pots in 8 concrete tanks.

Chemical analysis of the plant materials has not yet been completed but the significances of the analysis of variance on the growth

TABLE 42
Soil nitrogen and phosphorus effects in the pot experiment

Growth measurement	G	Main effects			GN	Gn	GP	Gp	Interactions		
		N	n	P					Nn	NP	Np
<i>Leaves</i>											
Fresh weight	***							*			
Dry weight	***			*				*			
Per cent dry matter							*				
Total area (sq. cm.) 36 wks.	***			*				*			
Total area (sq. cm.) 18 wks.	**		*					*			
Increase area per day 18-36 wks.	***	*		*				*			*
<i>Stems</i>											
Fresh weight	***	*						**			
Dry weight	***			**				*			
Per cent dry matter											
Girth (soil level)	***		**								
<i>Roots</i>											
Fresh weight	***							**		*	
Dry weight	***							*			
Per cent dry matter	***										

Significances are indicated as follows: ***, P = 0.1 per cent; **, P = 1 per cent; *, P = 5 per cent

measurements are given in Table 42. After the complete factorial analysis, the 'error' standard from the top interactions was improved by including those sums of squares which were not significant.

Main effects

It will be seen from Table 42 that the soil (G) differences were generally highly significant; this is reflected by all growth measurements with the exception of percentage dry matter in leaves and stems. Fresh and dry weights appear to be proportional in leaves and stems but not in roots.

Significant differences in the sources of nitrogen (N) were only reflected in increase in leaf area per day and fresh weight of stems: fresh weight of leaves, dry weight of stems and percentage dry matter of leaves were almost significant. Differences in levels of nitrogen (n) were significantly reflected in girth and leaf area at 18 weeks but only approaching significance in fresh and dry weights of leaves. The data also show that generally there was an initial depressive effect of nitrogen at level 1.

The effect of source of phosphorus (P) was significantly reflected in dry weight of leaves and stems, leaf area at 36 weeks but not at 18 weeks and in increase in leaf area per day. There was no significant differences between levels of phosphorus (p).

Interactions

No significant interactions occurred between soils and source of nitrogen (GN), and levels of nitrogen (Gn). The only significant interaction between soils and source of phosphorus (GP) was shown by percentage dry matter in leaves. Interaction between soils and levels of phosphorus (Gp) was generally significant, except for percentage dry matter of leaves, stems and roots, fresh weight of roots, girth of stems and increase in leaf area per day. It appears that although the levels of phosphorus are significant per soil type, the differences are by and large cancelled by the non-significance of the levels main effect.

The only significant interaction between sources of nitrogen and phosphorus (NP) is reflected in the dry weight of roots. Interaction between source of nitrogen and levels of phosphorus (Np) was nearly significant in percentage dry matter of leaves; and that between levels of nitrogen and levels of phosphorus (np) only significant in the increase in leaf area per day.

There were no significant interactions between nitrogen source and levels of nitrogen (Nn), phosphorus source and levels of phosphorus (Pp) or levels of nitrogen and source of phosphorus (nP).

Significances at the second order interactions may be spurious rather than real, and are therefore not reported here.

SHADE AND FERTILIZER EXPERIMENT (KI) — FOLIAR ANALYSIS

(J. C. Burr ridge, R. G. Lockard, and D. K. Acquaye)

The general pattern of macronutrient seasonal variation previously reported for this experiment (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 68) was repeated during 1961-62, and in view of this, regular frequent sampling has been discontinued.

The analyses for N, P, K, Ca and Mg in the 756 leaf samples (36 plots at 21 times) obtained between February 1960 and March 1962 are summarized in Table 43.

TABLE 43

Foliar analysis of shade and fertilizer experiment sampled February, 1960 to March 1962 (concentrations as per cent of oven dry matter)

Treatment	N	P	K	Ca	Mg
Fertilizer	2.13	0.179	2.26	1.05	0.59
No fertilizer	2.06	0.150	2.31	1.00	0.55
Difference (1)	+3.4***	+17.6***	-2.0***	+4.7***	+6.3***
Shade	2.13	0.175	2.44	0.93	0.57
No shade	2.06	0.155	2.14	1.13	0.57
Difference (1)	+3.4***	+12.1***	+13.3***	-19.1***	+0.2
Irrigated	2.08	0.165	2.27	1.01	0.56
Not irrigated	2.10	0.165	2.30	1.04	0.58
Difference (1)	-1.1**	+0.5	-1.4*	-3.3**	-1.9**
Seasonal maximum (2)	2.24	0.211	2.67	1.39	0.67
Seasonal minimum (2)	1.95	0.131	1.74	0.69	0.44
Overall mean	2.09	0.165	2.29	1.03	0.57
S.e. of mean	±0.004	±0.0008	±0.006	±0.005	±0.002

(1) The difference for the main effects of fertilizer, shade and irrigation have been expressed as percentages of the mean. Significant differences are: *, $P = 0.05$; **, $P = 0.001$ and ***, $P = 0.001$

(2) The seasonal maxima and minima are for the mean of all 36 plots at any one time

The level of significance for the main fertilizer, shade and irrigation effects are also indicated in this Table. It is hoped to publish a full discussion of the data elsewhere, but a few brief comments will be made here.

Effect of adding fertilizer

It can be seen from Table 43 that the N, P, Ca and Mg concentrations in the leaves have all increased where fertilizer has been applied. The greatest increase has occurred with phosphorus, and this agrees with other field experiments which indicate that phosphorus is the component of the compound fertilizer (N, P, K, Mg) which is chiefly responsible for yield increases. It is noteworthy that although potassium has been applied at a rate equivalent to 100 lb. K_2O per acre, the K concentration has been depressed, and it is tentatively suggested that an increased demand for K, stimulated by the other fertilizer components, exceeds the increased supply of K added as fertilizer.

Effect of shade removal

It has been fully reported previously (e.g. *Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, p. 63) that shade removal has led to greatly increased yields from this experiment. The lower levels of N, P, K and Mg in the unshaded cocoa are probably a reflection of an increased demand for nutrients resulting from the stimulus of shade removal. The opposite trend for Ca possibly results from an interaction with K, as indicated previously (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61, Figure 7, p. 71).

Effect of irrigation

It is chiefly of interest to note that whereas the N, K, Ca and Mg concentrations have all been slightly reduced by irrigation, the P concentration has remained unchanged.

Weekly samples of wet beans have been taken from this experiment since December, 1961 and it is planned to study the effect of the treatments on the bean composition.

SPECTROGRAPHIC ANALYSIS OF FOREST ZONE SOILS (J. C. BurrIDGE)

Nineteen soil profiles from the forest zone have been examined spectrographically and the large amount of data obtained has been prepared for publication in detail. Some results of this study are briefly reported here.

1. The majority of the concentrations found for Rb, Li, Ba, Sr, V, Cr, Co, Zr, Ni, Cu, Mo, Ga and Mn lay well within ranges that are commonly found. The most striking exceptions were one profile with an estimated Ba content of 3,000 - 10,000 ppm and two profiles with Co contents of 100-200 ppm.
2. There were no obvious trends within profiles which could be taken to indicate any significant leaching of trace elements.
3. Soil parent material had a marked influence on trace element content; the soils over Birrimian formations having generally higher contents than did the soils over granite or sand-stone.
4. Iron and aluminium contents, expressed conventionally as their oxides Fe_2O_3 and Al_2O_3 , both ranged from less than 1 per cent to approximately 30 per cent.

COCOA PREPARATION AND QUALITY

(H. W. S. Allison and R. H. Kenten)

ASSESSMENT RESULTS

Samples of Amelonado cocoa from tray fermentations of four days duration and from heap fermentations of four and six days duration together with samples of Amazon cocoa from tray fermentations of

five days duration and from heap fermentations of five and six days duration were sent for quality assessment to the Cocoa Scientific Advisory Committee of the United Kingdom (C.S.A.C.) who reported that, while there was some difference between individual samples, the range of variation was small and all samples were considered to be within the West African range. Quality assessments of cocoa from single and double tray fermentations were considered to be inconclusive and, consequently, further samples from the mid- and main-crops have been sent to C.S.A.C. Bulk samples of heap fermentations of different durations, turned first and second days or turned second and fourth days have also been sent.

MECHANICAL DRYING

Approximately 37 tons of dry cocoa was produced during the year. Bulk samples of mechanically dried main crop beans from tray fermentations of four, five and six days duration, and from sweat box fermentations of six days duration have been sent to the C.S.A.C. for quality assessment.

The main problems involved are to achieve a uniformly dried batch with few damaged beans or beans with brittle shell and to maintain an economy in fuel and labour, with a turn-over of one ton dried cocoa every 24 hours. Early experiments established that it was possible to dry one ton batches every 24 hours with a reasonable fuel consumption but a number of batches were not uniformly dried and contained a high proportion of broken beans. Uniformity of drying depends to a large extent upon the amount of mixing. However, the more mixing the greater the damage, particularly in the initial and final stages, when the beans appear to be more susceptible to injury. Mixing in the initial stages is essential, to avoid beans sticking together and drying in large clumps.

By varying the raking procedure and the temperature of the hot air, progress has been made towards establishing a satisfactory routine procedure. With recent experiments, we have reduced the proportion of damaged beans, improved the toughness of the shell, and to some extent, improved the uniformity of drying. We are now using an average of 35 gallons diesel fuel per ton of dry cocoa. The average labour costs have been five man-days per ton, as compared with thirty man-days per ton sun-dried. We are not yet consistently producing satisfactory results, however, and are consequently unable to recommend a routine procedure.

STATISTICS

(C. de Jonge)

The training of assistants to carry out routine analyses with the use of the electric calculating equipment continued throughout the year. There has, however, been a high turnover of staff owing to recruits with West African School Certificate leaving on scholarships for University education.

A further study was started on the distribution of 'numbers of pods'. Visual counts have been made on line-planted, non-experimental cocoa in an attempt to devise a suitable calibration method.

The computing room, completed a year previously, has been in constant use and has proved to be a great asset.

IBADAN STATION

VIRUS RESEARCH

MECHANICAL TRANSMISSION (Mrs P. C. Wessel-Reimens)

Work on mechanical transmission of cocoa swollen shoot viruses has continued and the investigations have been greatly facilitated by an ultracentrifuge, Spinco Model L, which was installed in October 1961.

Theobroma cacao, *Hildegardia barteri* and *Adansonia digitata* infected with different virus strains (mostly Offa-Igbo 159) were used as source plants; cocoa half beans, whole beans and sometimes newly germinated whole beans and cocoa seedlings were used as test-material. In some experiments beans and seedlings were heated in water at 50°C (beans for 60 secs., seedlings 10–15 secs.) before inoculation, Yarwood (Yarwood, C.E. 1956, *Phytopath.* **46**, 9: 523-525 and Yarwood, C.E. 1956, *Plant Dis. Repr.* **40**, 4: 299) having shown that peach seedlings are more susceptible to mechanical transmissions after such treatment.

Leaves from infected plants were ground in a buffer solution (0.07 M Phosphate or 0.2 M Tris) and a reducing agent (0.01 M L-cysteine hydrochloride or 0.1 M thioglycollic acid). In some experiments Al_2O_3 , and/or 0.01 M sodium diethyldithiocarbamate were added and in one experiment ethylenediamine tetraacetate was added. The pH of the fluid was always kept between 8.0 and 8.5.

The test material was treated with the squeezed sap; when enough source material was available to use the ultracentrifuge, the test-plants were treated with material obtained from the different steps. Carborundum or celite 545 was used as an abrasive, dusted on the beans and leaves or mixed in the inoculum.

In a few experiments flowers from infected cocoa trees were used as a virus source, but the sap was very mucilaginous.

In all this work although occasional faint symptoms appeared on some of the test-plants no clear evidence of transmission was got.

Since February 1962 the methods mentioned above have been abandoned and that developed by Brunt and Kenten, which has given satisfactory results in Ghana, has been adopted and is now being tested for the Nigerian strains. The first results, already obtained, are promising, successful transmissions having been obtained with a severe Ikire isolate.

VIRUS TOLERANCE (J. F. Longworth)

Alakia II Virus tolerance experiment

This experiment consists of twelve blocks, each containing nine varieties. Fifteen varieties were represented in the trial but some are not present in all blocks and conclusions affecting those with the lowest replication (L and C replicated twice, F three times) are made with some reservation. The seedlings were planted in 1959 at 4' by 4' spacing. There were ten seedlings per plot, five being graft-infected with a virulent isolate of CSSV from Ikire and five retained as healthy controls.

Table 44 shows the results of analyses of incremental changes in stem diameter since infection.

TABLE 44

Increments in stem diameter (February 1960 – December 1961), for infected and non-infected trees in Alakia II Tolerance Experiment and the reduction in growth caused by infection***

Variety	Infected trees	Variety	Healthy trees	Variety	Healthy minus infected	Variety	Reduction (per cent)
L	-1.509	H	-0.464	A	+2.936	L	45.7
S	-0.451	F	+0.482	D	+2.788	A	42.3
H	-0.215	M	+1.372	J	+2.421	S	31.0
M	+0.145	G	+1.625	L	+2.372	D	30.6
F	+0.517	L	+1.691	S	+2.144	J	29.9
E	+0.600	E	+1.865	T	+1.157	E	26.4
G	+0.820	S	+2.301	N	+1.096	M	25.1
T	+1.159	T	+2.430	E	+1.085	N	24.9
A	+1.320	A	+2.556	M	+1.000	G	24.5
N	+1.569	K	+2.665	C	+0.759	T	24.2
J	+1.813	N	+2.706	G	+0.742	C	22.9
D	+1.949	C	+2.818	K	+0.191	R	19.1
C	+2.201	J	+4.570	F	+0.014	F	18.5
K	+2.860	D	+5.144	H	-0.215	H	17.8
						K	17.3

* Expressed as the difference between each adjusted variety mean and that of the Amelonado control (R), as a multiple of the standard error of that difference; thus a value greater than 2 indicates a significance difference from the control

** (Non-infected – infected) adjusted means

Non-infected adjusted means

× 100

Most of the varieties, when healthy, grew better than the Amelonado control, D and J being outstanding. In none of the varieties was the percentage reduction in growth much less than that of the Amelonado control, which itself was relatively low. These Amazon hybrids, therefore, did not show any evidence of tolerance, but there was a considerable range of susceptibility. Varieties like D ($T61 \times T61$; an F_2 Nanay hybrid) and J ($T60 \times T60$; an F_2 Nanay-Parinari hybrid) when infected had greater vigour than the Amelonado control in spite of a considerable reduction of growth. In contrast, K ($T79 \times T79$; an F_2 Nanay-Parinari hybrid) and C ($T81 \times T81$; an F_2 Nanay hybrid) were more vigorous than the control when infected or when healthy, and their reduction in growth as a result of infection was no greater than that of Amelonado. Most varieties were not significantly different from Amelonado in respect of either infected vigour or reduction of growth and only L (Series IIA; $T63$ Nanay-Parinari $\times$ Amelonado) appeared markedly worse in these respects. In general terms the performance of these varieties when infected depended on their inherent vigour, even though there was a considerable variation in susceptibility within them.

This preliminary investigation, amongst varieties which were not bred for tolerance, suggests that much of the Amazon material which has already been planted in Nigeria will, if it becomes infected, perform at least as well as the infected Amelonado population and that from amongst the Amazon types there is a great potential for breeding varieties of a high level of tolerance.

Alakia III Virus tolerance experiment

This trial consists of five Series II hybrids, one Series I hybrid, and a control 'variety' which in three of the six replicates is Amelonado and in the other three is Series I variety Q ($T(N)38 \times T(N)38$). These varieties were planted in randomized blocks in April 1960 at 4' by 4' spacing. Main plots were split for infection with a virulent isolate of CSSV from Ikire in August 1960. The results of analyses of increments in stem diameter since infection are presented in Table 45.

Varieties IID ($E1$, Trinitario, $\times$ $T16$ Iquitos) and IA ($T12 \times T12$, an F_2 Scavina hybrid) showed some degree of tolerance, whilst the other varieties (all Nanay-Parinari Amazon $\times$ either Amelonado or Trinitario) followed a similar trend to that in Alakia II in that their reaction to infection depended on their inherent vigour.

Both parents of IID showed some degree of tolerance in qualitative laboratory tests and in this trial IID itself showed a level of tolerance which recommends it for use in the 'Area of Mass Infection' in Nigeria, should it prove satisfactory in other respects. The apparent

tolerance of 1A contrasts with its performance in Alakia II (as variety H) and the tolerance of this and other Scavina hybrids will be investigated further.

TABLE 45

Mean increments in stem diameter (cm.) from August 1960 to December 1961, for infected and non-infected trees in Alakia III Tolerance experiment and the reduction in growth caused by infection

(a)		(b)		(c)		(d)
Variety	Infected trees	Variety	Healthy trees	Variety	Healthy minus infected	Reduction (per cent)
'Ad'	2.358	'Ad'	2.816	IIK	0.813	23.8
IIE	2.501	IIA	3.051	IIE	0.672	21.2
IIA	2.508	IIE	3.173	IIC	0.606	19.0
IIC	2.574	IIC	3.180	IIA	0.543	17.8
IIK	2.598	1A	3.260	'Ad'	0.458	16.3
1A	2.841	IID	3.302	1A	0.419	12.8
IID	2.983	IIK	3.411	IID	0.319	9.7

(a) Significant difference means (at $P = 0.05$) = 0.418

(b) No significant differences

(c) Significant difference between means (at $P = 0.05$) = 0.473

(d) (c) is expressed as a percentage of (a)

Interrelationship of effects of virus infection upon growth, severity of symptoms and incubation period

In both Alakia II and Alakia III tolerance experiments the use of a system of scoring symptoms according to their severity was investigated with a view to its use in future selection of tolerant varieties. The scores ranged from 0-5, as follows:

0 = Symptomless.

1 = Mild symptoms.

2 = Mild symptoms and/or slight swellings.

3 = Intermediate to severe symptoms and/or swellings.

4 = Severe symptoms, large swellings; obvious effect on growth.

5 = Very severe symptoms, swellings; dying back.

Symptoms were scored on five occasions at monthly intervals from June 1960 for Alakia II, and on two occasions for Alakia III in January and November 1961. The sequence of development of symptoms was observed frequently.

Figure 2 shows the relation between the percentage reduction in stem diameter and mean symptom score for each variety in Alakia II, based on adjusted variety means.

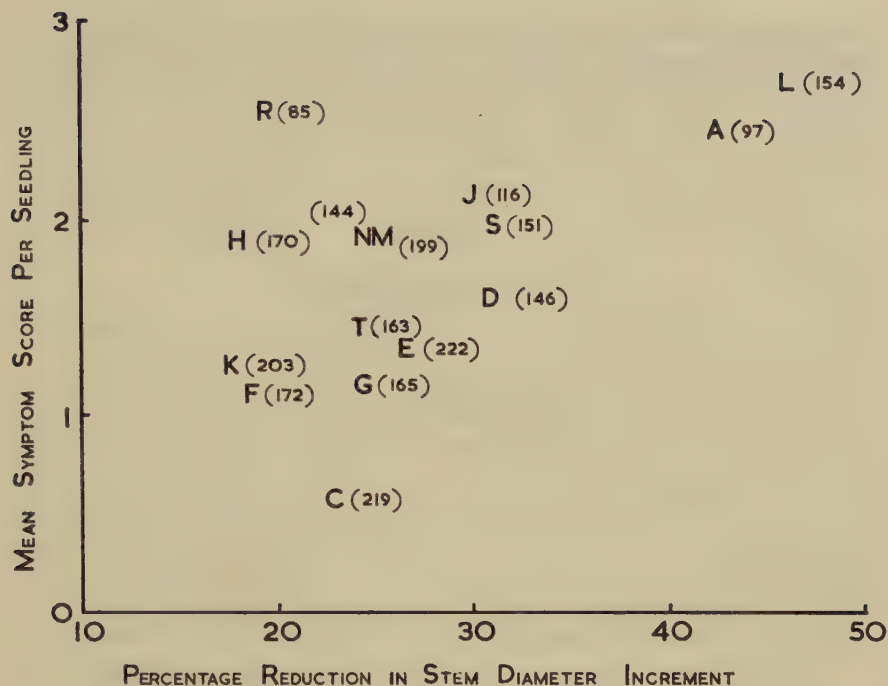


FIGURE 2. Alakia II Tolerance Experiment. The relation between percentage reduction in stem diameter increment and mean symptom score per seedling, for each variety (The mean number of days of the virus incubation period is shown in parenthesis)

The correlation between these two factors was $+0.574$ ($P = 0.05$). Amelonado (R), with a high symptom score, and a relatively low reduction in vigour did not follow the general trend, and the correlation between the two factors when the Amelonado control was excluded increased to $+0.746$ ($P = 0.01$). There was a correlation between mean symptom score and latent period after infection (data in parenthesis in Figure 2) both including the Amelonado control ($r = -0.732$, $P = 0.01$) and excluding it ($r = -0.676$, $P = 0.01$). The latter correlation lost significance when partial correlations were made to eliminate variation due to reduction in growth. The correlation between reduction in growth and latent period ($r = 0.559$, $P = 0.05$) lost significance after eliminating variation due to symptom score. Thus, excluding the Amelonado control, reduction in growth and latent period, and latent period and symptom score were related only because of the relation between symptom score and reduction in growth.

Similar data for Alakia III are shown in Figure 3. The means for the control 'variety' are included, as are the means of the two

components of the control (IQ and Amelonado) after adjustment for variation in blocks. The latter data were included in order to find whether Amelonado behaved as in Alakia II.

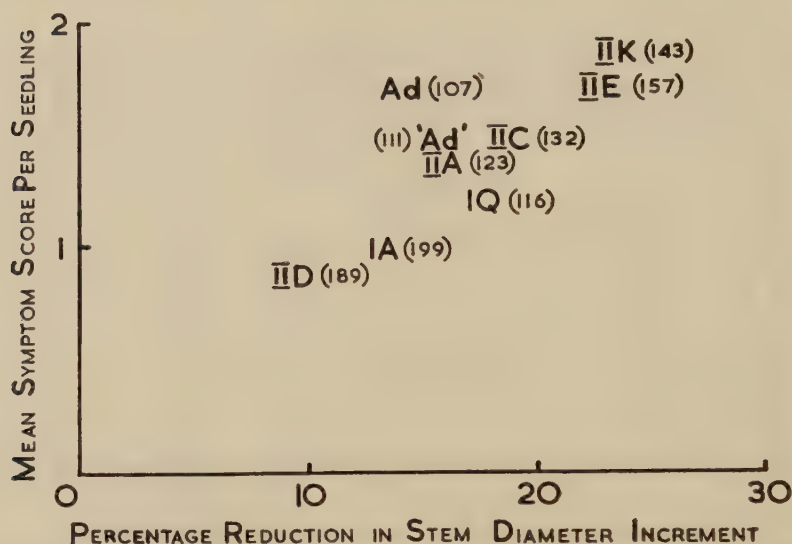


FIGURE 3. Alakia III Tolerance Experiment. The relation between percentage reduction in stem diameter increment and mean symptom score per seedling, for each variety (Mean number of days in the virus incubation period is shown in parenthesis)

Correlations between the varieties including the control 'variety' showed that symptom score and reduction in growth were related ($r = +0.964$, $P = 0.001$) and that the relation persisted after eliminating variation in the latency period ($r = +0.981$, $P = 0.001$). Symptom score and latent period were only related after eliminating variation due to reduction in growth.

Figure 3 shows that the Amelonado component of the control differed from the other varieties as in Alakia II, in that it had a low reduction in growth and a high symptom score. In fact the correlation between these factors, including Amelonado and IQ in place of the control, was $+0.902$ ($P = 0.01$), lower than that obtained when the components were treated together as the control 'variety'. This situation is similar to that in Alakia II when correlations between reduction in growth and symptom score were improved by excluding R, the Amelonado control. This implies that comparison of the tolerance of Amazon varieties and Amelonado made purely on the basis of severity of symptoms may lead to an overestimation of the tolerance of some Amazon types, and this may be an important factor in comparative laboratory tests.

Within the Amazon varieties, the high correlation between symptom score and reduction in growth indicates that scoring systems can be used with some confidence in the future in assessing the tolerance of hybrids bred for this character. This relationship has only been shown between populations, but its use in the selection of tolerant individuals within populations is being examined.

BLACK-POD STUDIES

STRAINS OF *Phytophthora Palmivora* BUTL. (G. Weststeijn)

In view of attempts to breed cocoa varieties resistant to black-pod disease, caused by *Phytophthora palmivora*, studies have been commenced on the occurrence of, and differences between, strains of this fungus within Nigeria.

The initial step was to select a suitable culture-medium on which the fungus would grow slowly but would nevertheless maintain a good vitality. Bean Pod Agar (Difco) met these requirements best and vitality tests with three different isolates on this medium showed that, after three months storage, all cultures remained viable. This experiment is being continued.

Large scale growth experiments on artificial media in petri-dishes are being executed. The isolates being studied are:

- (1) isolate No. 79228 of the collection of the Commonwealth Mycological Institute, isolated from cocoa leaves in Eastern Nigeria (C.M.I.);
- (2) an isolate from a seedling in Western Nigeria (S);
- (3, 4 & 5) three different isolates from pods in Western Nigeria (N-0, N-13 and N-14).

The culture-media examined to date are the following:

- (1) Czapek Dox Agar – Oxoid (CzDA);
- (2) Potato Dextrose Agar – Difco (PDA);
- (3) Wort Agar – Oxoid (WA);
- (4) Corn Meal Agar – Difco (CMA);
- (5) Sabouraud Fluid Medium Agar – Oxoid (SFMA);
- (6) Coon's Agar (CA);
- (7) Bean Pod Agar – Difco (BPA).

Each plate containing 10 cc. of the medium was inoculated with a circular disc (8 mm. dia.) of a culture from BPA, and was then incubated at 20°C. The growth-rate was calculated as the total of the measurements of the diameter of the colony along two perpendicular axes between the second and the sixth day. The results are given in Table 46 in which each figure is the mean of five replicates.

TABLE 46

Growth (in mm.) of isolates of P. palmivora on different media during four days of incubation

Medium	Isolate					5% sign. diff.	1% sign. diff.
	CMI	S	N-O	N-13	N-14		
CzDA	73.4	95.4	42.2	27.2	0	7.9	10.9
PDA	53.6	55.6	55.6	47.6	43.0	7.9	10.6
WA	23.8	20.4	13.8	11.0	20.2	12.1	16.5
CMA	77.0	89.2	56.8	54.4	40.8	9.7	13.3
SFMA	18.2	17.0	9.2	7.2	11.8*	4.4	6.0
CA	73.8	79.3	5.0	5.0	5.0	10.0	13.7
BPA	47.0	59.1	74.6	64.8	67.7	5.0**	6.6**

* As one datum of the N-14 culture on SFMA was missing, the significant differences for comparison of this isolate with others are respectively 4.7 and 6.4

** The growth-rates on BPA are based on 10 replicates each

Growth on Wort Agar and Sabouraud Fluid Medium Agar was so poor that no difference and only slight differences were detected respectively. On Potato Dextrose Agar, Corn Meal Agar and Bean Pod Agar there were significant differences in growth, but these were not as pronounced as on Czapek Dox Agar, where all isolates differed from each other at a 1 per cent level of significance. On Coon's Agar the CMI- and the S-isolate did not differ from each other, nor were there differences between the three Nigerian pod isolates. However, when comparing these two groups with each other, the CMI- and S-isolate differed in growth, at a 1 per cent level of significance, from each of the N-isolates.

The last two media mentioned appeared to be the most interesting. As the components are pure inorganic and organic chemicals studies will be continued especially with media of this type with subsequent modification of the formula.

The reliability of the length-breadth ratio of the sporangia as a character by which isolates can be distinguished, has been checked. It was found that the value of this ratio depends largely on the kind of culture medium used. The CMI-, S- and N-o isolates therefore were subsequently transmitted from N-38 Amelonado pods to Cassava Dextrose Agar (CaDA), then to Czapek Dox Agar and back to CaDA. The L/B-ratio was determined after a growth-period of seven to eight days on each of the artificial media. The temperature during the periods of growth was standardized at 20°C.

When grown on CaDA the shape of the sporangia of each isolate was found to be different from the shape of the sporangia of the same

isolate on CzDA ($P = < 0.01$). However, such a difference was also found when comparing cultures on the CaDA-medium at the beginning and end of the experiment. The actual differences are given in Table 47A.

TABLE 47

Length/breadth ratio of sporangia of isolates of P. palmivora as influenced by culture-media

A - Series I

Isolate	Medium		Cassava dext. agar	5% signif. diff.	1% signif. diff.
	Cassava dext. agar	Czapek dext. agar			
CMI	1.655	1.295	1.591	0.059	0.079
S	1.762	1.291	1.628	0.059	0.077
N-O	1.556	1.174	1.388	0.049	0.064

B - Series II

Isolate	Medium		Theobroma cacao N-38 pod	5% signif. diff.	1% signif. diff.
	Theobroma cacao N-38 pod	Herrania mariae T-67 pod			
CMI	1.690	1.496	1.795	0.073	0.095
S	1.633	1.507	1.583	0.063	0.082
N-O	1.373	1.387	1.297	0.039	0.052
N-13	1.353	1.326	1.302	0.035	0.046
N-14	1.384	1.357	1.348	0.045	0.059

C - Series III

Isolate	Medium		Theobroma cacao N-38 pod	5% signif. diff.	1% signif. diff.
	Theobroma cacao N-38 pod	Herrania mariae T-68 pod			
CMI	1.976	1.391	1.856	0.079	0.102
S	1.671	1.410	1.640	0.055	0.072
N-O	1.360	1.328	1.334	0.039	0.052

The same series of experiments was executed with natural culture-media, i.e. pods, using two more Nigerian pod isolates (N-13 and N-14). The isolates were transmitted from Bean Pod Agar to N-38 Amelonado pods, then to *Herrania* T-67 pods and back to N-38 Amelonado pods. The pods were incubated in closed plastic bags at practically 100 per cent r.h. and at about 21°C. The L/B-ratio was measured after seven days on each type of pod. A further series of experiments was carried out with *Herrania* T-68 pods as the intermediate medium.

The results are given in Tables 47B and C, and show how the shape of sporangia can be influenced by the culture-medium on which the growth actually takes place, and suggest that the preceding culture medium can also have an effect on sporangia shape. The influence was especially marked in the CMI-isolate, less pronounced on the S-isolate and nearly absent in the isolates from pods within Nigeria. For this reason the length-breadth ratio of the sporangia must be considered an unsuitable character for the exact distinction of strains.

BLACK-POD CONTROL (E. C. Hislop)

Fungicide Trial, 1961

Following the laboratory assessment of fungicides for black-pod control described in the previous Annual Report a number of fungicides were selected for further study in the field. The site used was once again the New Spacing Trial in the Gambari Experimental Station, although this year a better experimental design was employed. Eight treatments were distributed over the non-orthogonal 7×7 Latin square in such a way that the control was replicated seven times, i.e. once on each spacing regime, and each fungicide treatment replicated six times. Four hundred and forty-four control trees were recorded and the maximum and minimum number of treatment trees recorded were 406 and 302 respectively.

The fungicide treatments applied were:

- (1) 0.04 per cent triphenyl tin acetate.
- (2) 0.06 per cent triphenyl tin acetate.
- (3) 1 per cent Carbide Bordeaux mixture (10 lb. copper sulphate snow: 4 lb. calcium carbide: 100 gal. water).
- (4) 1 per cent Bordeaux mixture (10 lb. copper sulphate: 4 lb. calcium oxide: 100 gal. water).
- (5) 0.16 per cent Copper as copper oxychloride.
- (6) Unsprayed control.
- (7 & 8) 0.05 per cent and 0.10 per cent N-trichloromethylthio-4-cyclohexene-1, 2-dicarboximide, respectively.

Eight fungicide applications were made at three weekly intervals with pressurised knapsack sprayers. All trees were individually recorded for healthy and diseased pods prior to each fungicide application and for two months after the final spray. Details of the number of black-pods, total pods and percentage black-pod recorded at each harvesting date for each treatment are presented in Table 48.

TABLE 48
Summary of the number of black-pods (BP), total pods (TP) and black-pod percentage (BP%) recorded on each date for the different treatments

Formulation numbers	5				(Control) 6				1				8				4				2				7						
	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP	BP	TP			
			%				%				%				%				%			%				%			%		
15/6/61	19	38.3	4.96		14	27.3	5.13		51	51.2	9.95		30	48.2	6.2		18	64.1	3.9		16	31.4	5.1		29	52.3	5.3		63	47.2	13.35
8/7/61	74	62.5	11.8		66	90.0	7.33		217	76.3	28.4		96	90.9	10.56		620	113.9	54.43		255	88.6	28.78		113	97.8	11.55		236	46.7	50.54
28/7/61	68	25.7	26.46		16	26.4	6.06		93	19.4	47.9		38	17.3	21.97		128	31.2	41.0		17	34.1	4.99		53	28.8	18.4		92	20.7	44.4
17/8/61	13	33	39.39		19	55	34.55		27	37	73.33		9	35	25.71		55	68	80.88		26	75	34.67		53	87	60.91		8	22	36.36
8/9/61	8	13	61.54		1	7	14.71		6	6	100		1	2	50		6	8	75		5	12	41.67		7	7	100		1	1	100
30/9/61	24	69	34.78		17	76	22.37		19	75	25.33		17	56	30.36		14	52	26.92		15	57	26.32		23	94	24.47		11	29	37.93
20/10/61	610	839	72.71		442	763	57.93		798	942	84.71		490	776	63.14		691	843	81.97		592	866	68.36		511	728	70.19		620	745	83.22
14/11/61	117	361	32.4		144	478	30.1		271	517	52.4		94	442	21.3		158	401	39.4		174	547	31.8		135	451	29.9		120	298	40.3
2/12/61	12	577	2.1		21	100.8	2.1		23	76.5	3.0		16	706	2.3		10	560	1.8		16	821	1.9		11	570	1.9		10	509	1.96
29/12/61	—	393	—		3	543	0.55		—	427	—		—	370	—		1	338	0.29		4	582	0.69		1	475	0.21		—	273	—
Totals	945	3550	26.62		743	4367	17.01		1505	4238	35.51		791	3951	20.02		1701	4182	40.67		1120	4501	24.88		936	4201	22.28		1161	3023	38.41

An analysis of variance was carried out on the percentage black-pod transformed to angles of equal information. There was no correlation between black-pod percentage and total numbers of pods per unit area or per 100 trees. There was a very big effect of treatments ($P < 0.001$) and also a big effect of rows and spacings, that of spacing being largely accounted for by a linear trend. The black-pod percentage means, and their transformed values, for treatments, rows and spacings are presented in Table 49, where the significant differences given are for the 5 per cent level. It should be noted that the significant difference comparing any two fungicide treatments is not the same as that comparing the control and any treatment.

TABLE 49

Mean percentage black-pod, untransformed and transformed to angles of equal information, for treatments, rows and spacings with their five per cent significant differences

<i>Treatments</i>	1	2	3	4	5	6	7	8
<i>Black-pod %</i>	17.1	19.0	19.1	20.6	24.7	34.0	39.6	44.7
<i>Transformed %</i>	24.42	25.84	25.91	26.97	29.81	35.64	39.01	41.95

Significant difference between sprays = 7.771								
Significant difference between control and any spray = 7.343								

<i>Rows</i>	<i>T</i>	<i>U</i>	<i>V</i>	<i>W</i>	<i>X</i>	<i>Y</i>	<i>Z</i>	
<i>Black-pod %</i>	25.9	25.5	23.0	18.7	27.0	30.3	39.8	signif. diff.
<i>Transformed %</i>	30.56	30.30	28.66	25.63	31.29	33.41	39.12	7.021

<i>Spacings</i>	5' × 5'	6' × 6'	6' × 7½'	7½' × 7½'	10' × 10'	12' × 12'	15' × 15'	
<i>Black-pod %</i>	34.4	31.3	28.6	27.2	24.0	28.2	16.4	signif. diff.
<i>Transformed %</i>	39.89	34.03	32.32	31.41	29.35	32.06	23.92	7.021

Analyses of covariance were also carried out on numbers per 100 trees and per unit area of black-pods corrected for total numbers of pods, the effects of these adjustments being very marked.

In Table 50 mean numbers of black-pods per unit area are tabulated for treatments and spacings. It was not practicable to calculate significant differences for the adjusted spacing means, the effect of such adjustment being too large.

TABLE 50

Effect of treatments and spacing on the mean numbers of black-pods (BP) per unit area

Treatments Mean No. B.P.	1	3	2	5	4	7	6	8
Unadjusted	147.9	161.1	164.4	155.9	188.4	205.3	236.4	323.9
Adjusted	142.6	143.0	153.9	173.3	174.4	240.2	245.7	308.6
Significant difference comparing any two sprays = 81.70								
Significant difference comparing any spray and control = 77.20								
Spacings	5' × 5'	6' × 6'	6' × 7½'	7½' × 7½'	10' × 10'	12' × 12'	15' × 15'	
Unadjusted	386.1	277.4	206.1	232.7	98.1	122.4	68.1	
Adjusted	300.7	219.5	197.4	206.6	149.1	173.7	143.9	

Table 51 is comparable with Table 50 except that the mean numbers of black-pods per 100 trees are given. Once again it was not practicable to calculate the significant difference for spacings.

TABLE 51

Effect of treatments and spacing on the mean numbers of black-pods (BP) per 100 trees

Treatments Mean No. B.P.	1	3	2	4	5	6	7	8
Unadjusted	187.2	245.5	250.9	317.9	263.5	366.7	425.7	649.7
Adjusted	174.1	212.6	229.7	253.8	262.2	439.0	515.2	608.4
Significant difference comparing any two sprays = 206.26								
Significant difference comparing any spray and control = 194.90								
Spacings	5' × 5'	6' × 6'	6' × 7½'	7½' × 7½'	10' × 10'	12' × 12'	15' × 15'	
Unadjusted	258.6	303.6	244.5	367.9	280.6	500.2	427.2	
Adjusted	422.9	403.1	362.8	363.9	288.8	332.1	199.1	

The results of these three analyses can be summarized as follows. Treatment differences are more or less maintained for all analyses. The lowest concentration of triphenyl tin acetate (treatment 1) gave the lowest percentage black-pod and the lowest numbers of black-pods in all replicates. Treatments 2 and 3 were grouped with treatment 1 in being significantly better than the control. Lime Bordeaux mixture (treatment 4) was significantly better than the control on an analysis of percentages, but this difference was not so marked with the other methods of analysis. Treatment 5, a near colloidal preparation of copper oxychloride, also occupied an intermediate position between the better treatments and the control. The results by any method of analysis illustrate the complete failure of treatments 7 and 8 to control black-pod in the field.

All methods of analysis show that black-pod was worse at the closest spacings where the numbers of pods per unit area are greatest. However, numbers of pods per 100 trees increases with increasing spacing. The unadjusted numbers of black-pods presented in Table 50 show a marked linear trend with spacings ($P < 0.001$), but after adjustment the spacing effect was much reduced with the linear trend failing to reach significance at the 5 per cent level.

The unadjusted black-pod figures presented in Table 51 also show a marked linear trend on spacings ($P < 0.05$) but the effect of adjustment in this case was to remove this trend and almost to substitute one in the opposite direction.

Bearing in mind these results and comparing them with the marked linear trend with black-pod percentages, it is apparent that there is an effect of spacing itself additional to the effect of spacing on the total number of pods.

Spraying machinery assessment

Experiments have been initiated to examine the theoretical and actual effectiveness of several types of spraying machinery for use in black-pod disease control. Preliminary observations were designed to study the effectiveness of mist-blowers as compared with the high volume knapsack machines in common use in Nigeria. While there is little doubt that the latter machines are the most suitable in small-holdings they have their limitations. Given a reasonable yield of cocoa it takes about one man/day to spray an acre, and unless the swirl plate is removed from the nozzle, which is a wasteful procedure, the height which the spray can reach depends directly upon the length of the lance. Furthermore, it has been shown in laboratory measurements of fungicide tenacity that some advantage should be gained from a low volume deposit which dries more quickly than high volume deposits, and is thus less likely to be removed from the pod should rain fall within several hours of spraying.

The degree of black-pod control obtainable with any type of machine depends upon a number of factors, viz.:

- (1) The toxicity of the chemical sprayed.
- (2) The amount adhering to the pod.
- (3) The distribution of the deposit over the pod.
- (4) The tenacity of the deposit.

The first of these factors has been examined both in the laboratory and in the field and the results were presented in the previous Annual Report. Quantitative assessments of high volume deposits and their distribution have also been made and it is known that pods sprayed carefully to run off usually retain between $6-10 \mu\text{g. Cu./cm.}^2$ when

sprayed with a suspension containing 0.2 per cent copper. The distribution and amounts of low volume deposits applied with different machines have now also been studied.

The normal method of assessment of copper residues on pods has several disadvantages, namely a lengthy analytical procedure using expensive chemicals, and unavoidable errors in the calculation of the surface areas of distorted or ridged pods. To overcome the first disadvantage a technique was developed in which the amount of copper on a test surface was estimated following a simple colorimetric determination of a dye mixed with the fungicide. In the laboratory the water soluble dye kiton red was mixed with suspensions of cuprous oxide, copper oxychloride and Bordeaux mixture and pipetted or sprayed onto various test surfaces. When dry these surfaces were washed with water to dissolve the dye which was then measured colorimetrically. The recovery of dye from suspensions of Bordeaux mixture was not satisfactory and the cuprous oxide gave variable results, but with the copper oxychloride formulation used almost complete recovery of dye from paper and glass surfaces was obtained. On pod surfaces the recovery of dye was less satisfactory because of the physical difficulty of washing the pods properly and once again because of the difficulty of calculating pod surface area. Direct examination of the effect of mixing kiton red dye with copper oxychloride on the deposition of copper was not possible due to the difficulty of determining dye and copper in the same sample. However, when paper surfaces of uniform area were sprayed in the laboratory under standardized conditions with copper and copper/dye mixtures the theoretical deposits of copper based on the colorimetric estimation of the dye were very close to the actual deposits of copper as determined chemically.

To overcome the objections to using cocoa pods in the field, for the assessment of spray deposits from different machines, artificial pods were turned from blocks of wood. The artificial pods were made to resemble natural pods but were so shaped that top middle and bottom segments could be separately covered with pre-cut pieces of paper of known area. Two types of paper were used, a white blotting paper and a medium weight glossy duplicating paper. The glossy paper was the more satisfactory as the dye was recovered easily and the paper did not break up when shaken with water. The glossy paper was also found to be suitable for a determination of droplet sizes as the stain spread on this surface was only 2.9 times the diameter of droplets of known volume produced in a micro-pipette.

A quantitative analysis of deposits on artificial pods placed in predetermined positions in a selected tree and scattered at random in a second tree has been made for two mist-blowing machines. The

object of the experiments was to fix some of the variables effecting the amount of toxicant deposited on a given surface.

Portable motorised sprayer

The first machine examined was a shoulder mounted motorised sprayer in which the spray mist is produced in a high velocity air stream issuing from a single nozzle. In separate experiments the method of spraying, the emission rate and the concentration of the spray chemical were varied and the deposits on various segments of the artificial pods assayed. The general results obtained were as follows:

Method of spraying. It was immediately obvious that this machine could not be used as it is commonly used in capsid control, i.e. to produce a general mist. The amount of copper deposited on the artificial pods was in most cases far too small. The second method of spraying tried gave each tree a deliberate up and down sweep before proceeding to the next tree in the line. Here deposits were heavier but poorly distributed, the sides of artificial pods away from the direction of travel being poorly covered and the mean deposit of copper decreasing rapidly with increasing height up the tree. The directional nature of the spray was immediately obvious. In the next test each tree was given a deliberate up and down sweep from two opposite directions. This method of spraying did much to improve the cover over most pods but for those adjacent to the trunk a shadowing effect could still often be detected. The relatively high deposits which were obtainable on pods below about eight feet with this method did however draw attention to the way in which the quantity of chemical deposited fell off with increasing height so that at 14–18 feet even a slow and deliberate circling of the tree, whilst spraying the canopy, still gave relatively low deposits. Of these deposits it was also very obvious that in most cases more than three quarters of the total deposit was on the bottom segment of the pod, again demonstrating the directional nature of the spray.

Emission rate. The above general findings held even when the emission rate of the machine was varied over a wide range. As would be expected for a given fungicide concentration deposits were greater at the higher emission rates. At a constant emission rate the amount of chemical deposited on the artificial pods was also increased by increasing the concentration of the copper suspension. Therefore many combinations of method of spraying, emission rate and fungicide concentration are theoretically possible. In practice, however, the number of combinations is limited by other considerations, e.g. ease and speed of operation and economics. For example, the whole

object of mist-blowing would be defeated if the emission rate were increased beyond a certain level.

Concentration. In theory a given deposit can be obtained by cutting the emission rate and increasing the concentration of the spray fluid. However, the sprayability of the fungicide suspension then has a limiting effect. It is also the experience in other crops that disease control decreases when the emission rate is reduced below a certain level.

From the results obtained in these preliminary observations a series of experiments were designed using 24 artificial pods distributed throughout a well shaped Amazon tree. In all tests the tree was sprayed on calm days for 30 seconds and the emission rate and concentration were varied. The results of these tests are presented in Table 52 in which the mean deposit is based on that recovered from 11,136 cm.² of artificial pod surface.

TABLE 52

The effect of emission rate and fungicide concentration on the mean deposit of copper recovered from artificial pods sprayed with a shoulder mounted motorised mist-blower

<i>Shoulder mounted machine</i>	<i>Emission rate (cc./min.)</i>	<i>Gal./acre at 12' × 12' planting</i>	<i>Fungicide concentration</i>	<i>lb./acre Cu. at 12' × 12'</i>	<i>Mean deposit μg.Cu/cm²</i>
1	750	25.3	0.5% Cu	1.3	3.6
2	600	20.3	1.0% Cu	2.0	4.5
3	380	12.8	1.5% Cu	1.9	3.4

Tractor sprayer

The second machine tested was an automatic tractor mounted sprayer operated from the tractor power take-off. With this machine the spray fluid is atomised in an air stream issuing from a maximum of eight outlets. When all the nozzles are functioning a complete semi-circle of spray is produced. The amount of toxicant applied per acre with this machine depends upon the same factors as described for the shoulder mounted mist-blower, except that the speed of spraying is determined by the tractor speed, the variable human element being eliminated. A similar series of tests to those described for the shoulder mounted sprayer were carried out with this machine and the following general results were obtained.

Speed of tractor. This was primarily determined by the nature of the ground over which the tractor had to pass, and as this was very uneven a maximum possible speed was about 2 m.p.h. As the sprayer fan is driven from the tractor power take-off the tractor engine must

be run fast enough to give the correct air speed, and therefore maximum penetration. With the tractor used in these tests the engine to power take-off ratio was such that 1.5–1.6 m.p.h. was a better speed since in low ratio gear No. 2 this gave near optimum power take-off speed of about 530 r.p.m.

Method of spraying. These tests were carried out on trees planted on a 12' × 12' square and a reasonably uniform cover on artificial pods was obtained by driving the tractor along each row in one direction only and spraying the trees on both sides. The level of deposit aimed at in these preliminary tests may be rather high so that it should be possible to spray trees planted at 9' × 9' or 10' × 10' from every alternate row and still obtain a well distributed deposit. Deposits were lower at the top of the trees and the bottom segments of the pods sprayed with the tractor mounted machine again retained a large proportion of the total deposit.

Emission rate and fungicide concentration. A wide range of emission rates is available from the nozzle bank by selecting alternative metering orifices and varying the pump pressure. Combinations of emission rate and fungicide concentration are limited by considerations similar to those described for the shoulder mounted machine. In Table 53 the results of three tests are given. The tree in which the artificial pods were suspended was sprayed by the machine passing down each of two rows of trees on either side of the one in which this particular tree was located. All eight nozzles were operative and the variable orifice in each was the same size. This machine travelling at 1.6 m.p.h. covers an acre of cocoa spaced at 12' × 12' in about 35 minutes.

TABLE 53

The effect of emission rate, tractor speed and fungicide concentration on the mean deposit of copper recovered from artificial pods sprayed with an automatic tractor mounted mist-blowing machine

Tractor mounted machine	Tractor speed m.p.h.	Gal./acre	Fungicide con- cen- tration	lb/acre	Mean deposit μgm. Cu/cm. ²
		12' × 12' spacing		copper at 12' × 12'	
1	2.6	20	1.0% Cu	2.0	3.7
2	1.6	32	1.0% Cu	3.2	5.0
3	1.6	18	1.5% Cu	2.7	3.0

The droplet spectra of the spray mists produced by the two types of machine tested were examined using artificial pods covered with glossy paper. The spread factor for this type of paper was determined using a micro syringe and a 2 per cent copper oxychloride suspension

containing 0.5 per cent kiton red dye. As it is impossible to standardise the spraying procedure with different machines a direct comparison of droplet spectra is not valid unless large numbers of samples are examined.

However, since the deposit on the paper is a function of the number and size of the droplets the ratio of the mean deposit to the percentage surface area covered should be the same for well chosen representative samples. In Table 54 values for the mean deposit are based on large samples and the differences between them are significant ($P = 0.01$). At the time of this test the machines were operating at as near optimum fan speed as was possible and the emission rates were 600 and 6,000 cc. min. for the shoulder and tractor mounted machines respectively.

TABLE 54

*Mean droplet diameters as calculated from paper surfaces
sprayed with two types of mist-blowers*

<i>Machine</i>	<i>Mean droplet diameter</i>	<i>Number of droplets/ cm.²</i>	<i>% area covered</i>	<i>Mean deposit (11,136 cm.²)</i>	<i>Mean deposit/ % area</i>
Shoulder mounted	35.9 μ	372	0.38	3.8 $\mu\text{g}/\text{cm}^2$	10
Tractor mounted	44.2 μ	348	0.53	5.0 $\mu\text{g}/\text{cm}^2$	9.5

The similarity of the figures for the ratios of the mean deposits to the percentage area covered suggests that the small areas for droplet size determination were fairly typical. Although it is convenient to express the spectrum as a single figure, i.e., the arithmetic mean, probably a better measure is the mass median diameter, which figure does not mask the effect of the largest droplets in the spectrum. The mass median diameters of the deposits produced with the two machines were calculated approximately as 55 and 89 microns for the smaller and larger machines, respectively.

During the coming black-pod season the shoulder mounted and the tractor mounted machines will be compared in the field with conventional knapsack sprayers. Each type of machine will be used to spray a $2\frac{1}{2}$ acre block of Amazon cocoa. The fungicide to be used will be Bordeaux mixture and the concentration, emission and spraying rates based on the theoretical assessment described above will be as follows:

- (1) Shoulder mounted machine. 4 per cent Bordeaux mixture sprayed at the rate of 600 cc./min. and applying approximately 20 gal./acre (300 trees).

- (2) Tractor mounted machine. 4 per cent Bordeaux mixture sprayed at 6,000 cc./min. and applying approximately 32 gal./acre.

ENTOMOLOGY

(P. F. Entwistle)

SHOT-HOLE BORERS

Seasonal incidence in cocoa

Table 55 shows the cumulative incidence of *Xyleborus morstatti* Hag. (Coleoptera. Scolytidae) per 100 cocoa seedlings in six trials during their first year in the field.

Attack probably begins in August and continues until at least the following March, the peak of activity lying between December and March but varying within this period with the area and the year of observation.

Factors affecting the degree of attack were discussed in the previous Annual Report. The relatively higher degree of infestation in Alakia I than in other plots can only be attributed to this area having been adjacent to bush, which may have contained wild host plants, on three sides.

Gallery development and the biology of reproduction in relation to cocoa

Observations made in 1960-61 (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61) on the development of galleries and the infrequency with which breeding takes place on cocoa in Western Nigeria, have been confirmed by further observations during the present year. However, it is known that the extent of gallery development may be quite different in other areas. Attacked seedlings received from Sierra Leone in 1959 showed a high proportion of fully developed galleries in many of which breeding had occurred, and in 1962 seedlings from Arochuku in the Eastern Region of Nigeria showed a similar condition. Table 56 compares the sample received from Arochuku with bulked data collected in Ibadan Province in Western Nigeria during the period 1960-62.

At Tafo in Ghana attack by *X. morstatti* is unusual, a situation which also seems to apply in the Cameroun Republic where it has been reported by various people not to occur on cocoa, though it is a serious pest of coffee in the same area.

These facts point to the development of local races of *X. morstatti* biologically distinct in their behaviour in cocoa, in distinction to the effects of locally different climatic and cultural conditions.

It has been pointed out previously (*Rep. W. Afr. Cocoa Res. Inst.*, 1960-61) that gallery development appeared not to differ with

TABLE 55

*Fluctuations in numbers of galleries of X. morstatti in seedling cocoa during the first year after planting in the field.
Data in terms of attacks/100 plants (a dash indicates no record taken in the month concerned)*

Locality	Month	July	August	September	October	November	December	January	February	March	April	May	June
Alakia I.		—	—	—	—	—	—	55.0	80.0	91.0	—	—	91.0
(1959/60)													
Gambari Shot Hole Borer Expt. I		—	—	—	4.0	6.0	7.0	8.0	9.0	9.0	9.0	—	—
(1960/61)													
Araromi		—	—	1.2	5.4	8.2	14.6	16.1	17.0	17.5	—	—	—
(1960/61)													
Gambari Shot Hole Borer Expt. III		—	—	1.8	2.5	3.2	3.9	4.7	5.7	7.5	} Records still to be taken after March 1962		
(1961/62)													
Gambari Shot Hole Borer Expt. V		—	—	—	0.2	2.2	5.5	8.5	11.0	11.8			
(1961/62)													
Gambari Coffee Plot Experiment		0	0	0	0	3.4	11.9	20.3	22.8	24.1			
(1961/62)													

TABLE 56

Comparative data on development of Galleries of X. morstatti on cocoa in Ibadan Province, Western Nigeria and Arochuku in Eastern Nigeria

Locality	Number of galleries examined	Brood chamber present	Breeding	Mean gallery score
Ibadan Province	485	19	3	2.31
Arochuku, Eastern Region	68	28	24	4.16

availability of water to the seedling. Furthermore, the data from Ibadan Province in Table 56 are an aggregate of eight separate experiments and cover three years observations and a series of very widely different cultural treatments in plots both in savannah and forest areas. Despite this the mean gallery score ranged only between 1.74 and 2.86, which is well below the figure of 4.16 for Arochuku.

Evidence to suggest how local races could arise results from observations on the biology of reproduction on coffee in Western Nigeria. The ratio of males to females is 1:10, within a range of 0:10 to 1:2, the male being about one third the size of the female and flightless, with very greatly reduced metathoracic wings. Mating occurs in the parent gallery between offspring of the same parent, young adult females normally having been fertilised within two days after pupal ecdysis. Females artificially isolated in the pupal stage, and virgin as adults, produced only male progeny when caged on coffee. Although the chromosomal constitution has not yet been determined it is believed that the males are haploid and that sex is determined by fertilization. This type of parthenogenesis, known as arrhenotoky, appears to be rare in the Coleoptera but, where it occurs in other orders of insects, males are generally less common than females and the sex ratio tends to be very variable.

Examination of large numbers of galleries on coffee in the field showed that 14 per cent of female progeny had no access to males in the parent gallery because more than half the galleries with ten or less progeny contained no males. However, galleries with purely male progeny did not occur naturally, suggesting that those females without initial access to males either failed to breed or mated with males from elsewhere.

The local differences in reproductive behaviour on cocoa may result from complete or intensive inbreeding following on reproduction in 'closed galleries' leading to a slowing down of gene flow and a localisation of variability. Whether inbreeding is complete is not yet known.

The practical implication of this theory is that the existence within a single country of local races of very different degrees of

activity on cocoa indicates the need for intranational quarantine precautions.

EARIAS BIPLAGA

In the larval stage *Earias biplaga* Wlk. (Lepidoptera, Noctuidae), a common pest of cotton in Africa, devours the apical buds and flush leaves of cocoa. It has been recorded as a pest of cocoa in many parts of West Africa and in the Western Region of Nigeria; it is a generally held opinion that its activities are one of the limiting factors to satisfactory establishment. Attack appears to be greatest during the first two years in the field, but extends beyond this period.

Since the present studies commenced in September 1961, large numbers of *Earias* adults have been reared from cocoa in Ibadan Province and all have proved to be *E. biplaga*. Cocoa seedlings placed next to a plot of cotton at Ilora infested with both *E. insulana* Bois. and *E. biplaga* were attacked only by the latter species.

Host plants of the genus *Earias* occur mainly in the Malvales, the two principal representatives of which in the Gambari area, where the experiments reported below are being conducted, are *Sida caprinifolia* and *Abutilon mauritianum*: *Earias* adults reared from these two host plants included only one example of *E. insulana*, the remainder being *E. biplaga*. The widely cultivated *Hibiscus esculentus* (okra) doubtless occurs in this area but has yet to be investigated; at Ilora, which is in the savannah, this species was attacked by *E. biplaga*.

Only one instance of bud destruction on cocoa by a species other than *E. biplaga* has been observed, but the adult of this moth has not yet been identified.

Insufficient data are available for a full analysis of oviposition siting but of 140 eggs noted on first year seedlings in the field 66 were on leaf stipules, 32 on the stem (of which 20 were on leaf scars), three on the apical bud and 34 on the upperside of the leaf between the middle and the base of the lamina. It seems then, that the stem (inclusive of stipules) is the most favoured oviposition site and that the leaves are used less commonly. Eggs were normally laid singly, but occasionally in groups of two or three.

Bud destruction seems to be largely effected by the early instars, the discarded head capsules of which are commonly to be found inside the destroyed bud, though, especially when flush leaves are absent, older larvae may feed in the same way and will occasionally burrow down the stem for a short distance below the apex.

Parasitism

A number of Hymenoptera have been noted as parasitic on *E. biplaga* but none have yet been identified. They comprise one species

on the eggs, one on the early instar larvae and four species which emerged from pupae but which probably originated from attack in the larval stage. The value of these parasites as checks on host numbers has not yet been assessed but the first appears to occur in up to 60 per cent of eggs.

Life cycle

From observations in the laboratory preliminary data are available on the duration of the life cycle (see Table 57).

TABLE 57
The pre-adult life cycle of E. biplaga

<i>Stages</i>	<i>Range</i>	<i>Mean</i>
<i>Incubation period</i>	4 - 5	4.3
<i>Larval period</i>	11 - 17	13.8
<i>Pupal period</i>	9 - 12	10.0
<i>Total pre-adult period</i>	24 - 34	28.1

The pupal period for females was only fractionally shorter than that for males and hence a mean for both sexes together is given in the table. In captivity the adult has been recorded ovipositing within three days of emergence from the pupa, so that the mean duration of the life cycle from egg to egg is in the region of 31 days. These observations agree very well with results obtained by Pomeroy, A. W. T. (1925, *The cotton boll worms of Southern Nigeria*, 4th Ann. Bull. Agric. Dept. Nigeria, p. 89-108) for the same species on cotton.

The longevity of adults depends on their diet and preliminary data is presented in Table 58.

TABLE 58
Longevity of adults of E. biplaga in captivity

<i>Diet</i>	<i>Males</i>		<i>Females</i>		<i>Mean for both sexes</i>	
	<i>Mean</i>	<i>Range</i>	<i>Mean</i>	<i>Range</i>	<i>Mean</i>	<i>Range</i>
<i>Nil</i>	3.0	1 - 5	2.20	1 - 3	2.63	1 - 5
<i>Tap water</i>	6.14	1 - 14	6.57	1 - 10	6.32	1 - 14
<i>Tap water and cane sugar</i>	17.28	2 - 36	28.70	2 - 48	23.50	2 - 48

It is apparent that the addition of cane sugar has a considerable effect on length of life. The relationship of diet to fertility and fecundity is currently being studied, following the development of what appears to be a suitable *in vitro* technique for mating and oviposition; the results will be reported at a later date.

Population changes

Preliminary data for the period October 1960 to September 1961 are available as a result of monthly collections of lepidopterous larvae made in Gambari Shot-hole Borer Experiment I. More exact data have been collected for the period September 1961 to March 1962 (the date of writing) from the series of plots listed below, all of which were planted in the wet season of 1961.

Insect Observation Plot I: this consists of ten plots arranged in two rows of five. Each plot contains 176 seedlings, alternate plots being shaded with palm fronds supported on bamboo poles at six feet above ground level. At weekly intervals counts of *Earias* larvae, and those of other Lepidoptera are made and from half of each plot all larvae other than *Earias* are removed and identified; the object of this is to determine the effects of other Lepidoptera and *Earias* together, and of *Earias* alone.

Insect Observation Plot II: a rectangular plot containing 1,980 seedlings on which counts of *Earias* larvae, and those of other Lepidoptera are being made at weekly intervals. The plot is not shaded.

Seedling Establishment Trial II: a rectangular area of four rows of sixteen plots, each plot containing twenty seedlings. Counts of both *Earias* larvae and those of other Lepidoptera are made at fortnightly intervals and all larvae other than those of *Earias* are removed for identification from two of the blocks. The area is not shaded.

Gambari Shot-hole Borer Experiment V: ten plots arranged in two rows of five, each plot containing 120 seedlings. Counts of *Earias* larvae and those of other Lepidoptera are made at weekly intervals and all larvae other than *Earias* are removed for identification from alternate plots. The area is under fairly dense forest shade.

In all plots regular estimations of bud destruction, regeneration, numbers of flush and hardened leaves, height and girth are being recorded. During the dry season, plots were watered when necessary as past experience has shown that, especially in unshaded areas, so many plants may die of drought as to render an experiment valueless.

Gross population changes, expressed as numbers of visible larvae per hundred plants are given in Table 59.

The general pattern shown by these data is that two population peaks have occurred so far, one between November and December and the other in the following March, numbers falling to a very low level in between. The last peak is the largest and followed on the first rains of the dry season, just as the first appeared to follow on

TABLE 59
Changes in numbers of larvae of *E. biplaga* (larvae/100 living plants)

	September				October				November				December				January				February				March			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Seedling Est.																												
Trial II	—	0.5	—	3.4	—	4.7	—	9.8	—	10.7	—	14.8	—	6.0	—	20.6	—	8.7	—	3.4	—	6.5	—	11.4	—	41.6	—	22.2
Insect Obser.	—	—	—	—	—	—	—	—	—	—	—	—	5.7	—	—	—	2.0	2.2	2.0	3.8	2.7	4.0	5.6	12.9	16.9	25.3	15.5	18.0
Plot II	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Insect Obser.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Plot I Unshaded	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
As above	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
but shaded	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gambari *S.H.B.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Exp. V	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Weekly rainfall	0.1	0.1	3.9	3.0	1.4	3.0	1.3	1.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.0	4.5	3.0
(inches)																									1.6	1.6	3.0	0.9

*S.H.B. = Shot-hole Borer

rains breaking a short drought in the previous wet season (rainfall figures are included in Table 59). However, it is not suggested that population changes are directly the result of rainfall; it is probable that they are associated with an increase in available feeding sites in the swift regeneration and flush that follows. The situation will be analysed when a full year's data are available.

Data collected on Gambari Shot-hole Borer Experiment I showed a very similar pattern of events, the population peaks being in November 1960 and April 1961. This experiment compared shade and no shade treatments and as in Insect Observation Plot I populations on the shaded plots remained below those of the unshaded plots until the March/April (respectively) peak, when the position was reversed. This was possibly the result of population pressure, the shaded plants being in much better condition after the dry season than the unshaded ones; support for this theory comes from the last mentioned area where populations on the shaded plots did not exceed those on the unshaded plots until a peak had been attained on the latter and considerable damage effected.

Similarly, populations on Gambari Shot-hole Borer Experiment V, under forest shade, were much lower than on exposed plots. Apart from a single larva noted in November, *Earias* was absent until the second week in February.

The populations shown in Table 59 are an under estimate, in that they take no account of those larvae active inside buds.

Table 60 summarises the effects of attack by *Earias* up to the end of March.

TABLE 60

Effects of attack by E. biplaga on shaded and unshaded seedlings

	% Plants destroyed apically	% Plants jorquetted	No. of lateral growths per plant
<i>Seedling Establishment Trial II. (No shade)</i>	72.00	0.00	6.00
<i>Insect Observation Plot I. (No shade)</i>	71.94	0.00	2.83
<i>Insect Observation Plot I. (Shade)</i>	29.68	21.13	0.45
<i>Gambari Shot-hole Borer Expt. V. (Natural forest shade)</i>	25.39	9.25	0.74

In unshaded areas three quarters of the plants had been damaged apically and no jorquettes had been formed. The mean number of regenerative lateral growths per plant was high. On shaded areas,

TABLE 61

Changes in numbers of lepidopterous larvae (except E. biplaga) on seedlings shaded and not shaded in Gambari Shot-hole Borer Experiment I, 1960-61 (larvae/100 living plants)

	October	November	December	January	February	March	April	May	June	July	August	September	October
<i>Shade</i>	0.98	5.08	2.50	1.79	0.80	0.36	1.84	3.67	1.80	1.91	1.91 +	4.97	2.86
<i>No shade</i>	0.71	3.03	1.35	0.90	0.00	0.42	1.08	1.14	0.75	0.98	1.12	20.4	1.57

however, only a quarter of the total plants had been damaged apically and jorquetting was in evidence. The mean number of regenerative lateral growths per plant was low.

MINOR PESTS

Seasonal changes in numbers of lepidoptera

In the previous Annual Report changes in numbers of Lepidopterous larvae (including *E. biplaga*) in Gambari Shot-hole Borer Experiment I, which compared shade and no shade treatments, were given for the period November 1960 to March 1961. In Table 61 the whole twelve months data for this plot are given in terms of numbers of larvae (but excluding *E. biplaga*) per 100 living plants.

Additional data are given for the present year (Table 62) from information collected from the plots discussed under *E. biplaga* above. This data covers only seven months, but from it and the preceding table, it is apparent that for both exposed and artificially shaded cocoa seedlings populations have been low, but that large numbers of larvae have at times been present beneath forest tree shade. With the exception of the last condition it seems that Lepidoptera other than *E. biplaga* are generally of little importance to seedling cocoa.

The composition of the lepidopterous populations studied was complex, comprising over 50 species, the least common ones of which have not yet been identified. Hence in Table 63, which deals with frequency of occurrence, sub-division is largely at family level with only the commoner species distinguished individually. The table is not intended as an accurate guide to population changes since it takes no account of the numbers of plants alive in any one month; conclusions from it can only be of a general nature.

As a family, the Psychidae were the most frequent and in most plots made up the bulk, and at times the whole, of the dry season population. This is probably a function of the long duration of the larval stage. The two most common single species outside the Psychidae, were *Anomis leona* Schaus. and *Prodenia litura* Fab.; numbers of *Lophocrama phoenicochlora* Hmps. are surprisingly low as this species was encountered much more frequently in experiments in the same general area in the preceding year.

Population charges of minor pests other than Lepidoptera

Monthly estimates of numbers of several non-lepidoptera minor pests were commenced on Gambari Shot-hole Borer Experiment I in October 1960, and reported for the six months ending March 1961

TABLE 62

Changes in numbers of lepidopterous larvae on several plots; 1961-62 (larvae/100 living plants)

[illegible]

TABLE 63

The composition of populations of larval lepidoptera (excluding *E. biplaga*) on seedling cocoa at Gambari:
September 1961 — March 1962

Month	<i>Anomis leona</i>	<i>Lophocrana phoenicochlora</i>	<i>Prodenia litura</i>	<i>Limacodidae</i>	<i>Lymantriidae</i>	<i>Arctiidae</i>	<i>Geometridae</i>	<i>Tortricidae</i>	<i>Psychidae</i>	<i>Unidentified</i>	Totals
September	—	—	—	8	17	4	3	—	20	5	56
October	6	2	28	3	40	6	9	5	60	7	166
November	3	2	38	8	114	2	4	4	125	13	313
December	20	1	7	5	4	2	2	2	52	13	108
January	22	1	3	6	1	—	3	—	80	6	122
February	2	—	1	—	—	—	1	—	39	—	43
March	4	—	15	3	1	56	7	2	48	346	482
Totals	57	6	92	33	177	70	29	13	424	390	1,291

TABLE 64

Fluctuations in incidence of several minor pests of cocoa on shaded and unshaded seedlings during the period April to October 1961 (expressed as percentage of plants infested)

Month	Shaded plants					Spider mite	Unshaded plants					
	<i>F. virgata</i>	Other m'bugs	Aphidae	Psyllidae	Thrips		<i>F. virgata</i>	Other m'bugs	Aphidae	Psyllidae	Thrips	
April	40.9	9.6	0.0	10.0	1.5	2.9	15.9	1.6	0.0	1.0	0.5	1.6
May	26.3	3.3	0.0	23.3	0.0	0.0	14.6	0.6	0.0	5.0	0.0	0.0
June	1.8	6.6	0.0	20.3	0.4	1.5	8.1	1.7	0.0	4.6	1.1	0.0
July	0.4	8.8	0.0	24.7	0.0	0.0	4.1	0.6	0.0	2.9	0.0	1.2
August	0.0	2.6	1.8	20.1	1.1	0.0	1.4	0.0	0.7	2.7	0.0	0.0
September	0.0	1.1	2.2	51.5	1.8	1.1	2.2	0.7	1.4	7.9	5.0	0.0
October	0.0	0.4	0.0	43.1	0.4	0.0	0.0	0.0	0.0	5.6	0.8	0.0

in the previous Annual Report. Table 64 completes a year's observations on this plot by giving data for the seven months ending in October, 1961.

Changes in numbers of plants infected by any one species on shaded and unshaded plots agreed well, though the incidence of any species was consistently lower on the unshaded plants. No one species behaved in a way comparable with any other; *Ferrisiana virgata* (Ckll.) had a single population peak in April/May, whilst for other mealybugs (mainly the *Planococcoides njalensis* (Laing), *Planococcus citri* (Risso) and *Planococcus kenyae* (Le Pelley) complex) the peak was spread over the wet months of April to July; the main peak for aphids (*Toxoptera aurantii* (B. de F.)) was in November, 1960, with another slight increase in September, 1961; psyllids (*Mesohomotoma tessmani* (Aulm.)) had an abrupt brief increase in January and a fairly steady increase from April up to September, 1961; thrips (*Selenothrips rubrocinctus* Giard.) were most prevalent in January and February whilst spider mite (*Tetranychus* sp., probably undescribed) declined steadily from a peak in December, 1960 to be practically absent during the last month of observation.

NEMATOTOLOGY

This programme is being carried out in conjunction with Dr F. E. Caveness of the Western Region Ministry of Agriculture and Natural Resources. (IDS/ICA Specialists Section).

Plant parasitic nematodes found associated with the roots of cocoa trees in Western Nigeria number about 24 genera and species. (Table 65). There is no doubt that future observations will add to the list.

A soil fumigation trial was initiated with the objective of determining the phytotoxic reaction of mature cocoa trees and cocoa seedlings to nemagon (1, 2-dibromo-3-chloropropane) at rates of one-eighth through 16 imperial gallons of active material per acre. The fumigant was injected at a depth of eight inches in the field and the midway point in each pot for seedlings. The ground area covered surrounding each tree at each rate of application was 100, 50 and 25 per cent. Each treatment was replicated four times.

Soil samples were taken prior to soil fumigation as well as after treatment at one replicate of each application rate at a depth of six and eighteen inches. Plotting the plant parasitic nematode population densities before and after treatment at each dosage rate at both depths we find that nematode control is achieved at the four gallon per acre rate.

TABLE 65

*Plant parasitic nematodes found associated with
cocoa tree roots in Western Nigeria*

<i>Scientific Name</i>	<i>Common Name</i>
<i>Xiphinema ebriense</i>	Dagger nematode group
<i>Xiphinema nigeriense</i>	Nigerian dagger nematode
<i>Xiphinema attorodorum</i>	
<i>Xiphinema ifacolum</i>	
<i>Xiphinema longicaudatum</i>	
<i>Xiphinema setarie</i>	
<i>Xiphinema sp.</i> (ad)	
<i>Xiphinema sp.</i> (x)	
<i>Helicotylenchus multicinctus</i>	Cobb's spiral nematode
<i>Helicotylenchus nannus</i>	Steiner's spiral nematode
<i>Helicotylenchus spp.</i>	Spiral nematodes
<i>Hemicyclophora oostenbrinki</i>	Oostenbrinki's sheath nematode
<i>Hemicyclophora sp.</i>	Sheath nematode
<i>Hemicriconemoides cocophilus</i>	Loos's sheathoid nematode
<i>Heterodera</i> (?) <i>larvae</i>	Cyst forming nematodes
<i>Hoplolaimus proporicus</i>	Goodey's lance nematode
<i>Meloidogyne incognita</i>	Southern root-knot nematode
<i>Meloidogyne incognita acrita</i>	Cotton root-knot nematode
<i>Criconemoides spp.</i>	Ring nematodes
<i>Paratylenchus curvatus</i>	Pin nematode
<i>Pratylenchus brachyurus</i>	Godfrey's root-lesion nematode
<i>Scutellonema spp.</i>	Spiral nematodes
<i>Tylenchorhynchus martini</i> (?)	Sugar cane stylet nematode
<i>Trichodorus sp.</i>	Stubby root nematodes

A site has been made available at Elepo for a replicated field trial of nematode control on cocoa. This plot will be fumigated in May, 1962.

Investigations into the inter-relationships of plant parasitic nematode, cocoa trees and banana shade plants have been initiated. The theory being investigated is that banana, being an excellent host plant for many types of nematodes, may act as a reservoir host, maintaining a large and constant parasitic nematode population detrimental to associated cocoa trees. This work should cover one or more years.

PLANT BREEDING

HISTORY OF COCOA BREEDING IN NIGERIA AND THE PRESENT OUTLOOK (H. Toxopeus)

In 1931 a selection and breeding programme in cocoa was initiated by Voelcker on Moor Plantation at Ibadan. Nineteen trees were finally selected from a plot of so called 'yellow podded Amelonado' which was planted in 1912 from an unknown seed source. Selection criteria were numbers of pods per year, numbers of beans per pod and numbers of beans per pound weight of fermented and dried

cocoa. The second step in this programme consisted of a comparison of the selfed and crossed progenies of a number of these selections, but the outcome was disappointing and for a variety of reasons no significantly different results could be obtained. Attention was concentrated on one selection called T38* and clonal plots were laid out for future seed gardens. To obtain new material for the breeding programme introductions from Trinidad and Ceylon were made, and in 1933 seedlings from open pollination of ICS₁, ICS₄ and a Ceylon selection were planted out in the field.

In 1941 the best of these introductions were selfed, crossed with N38 and also crossed with selections from a selfed N38 progeny. Hybrid vigour was recorded on the progenies of N38 × the Trinidad selections in 1952. As a result it was decided to raise clonal seed gardens consisting of the two parent genotypes of the best progeny. Unfortunately none of the parents was self incompatible so that the seed had to be raised by hand pollination. At the time that these seed gardens began to produce, the very promising characters of Posnette's Amazon introductions into Ghana became known and the W.A.C.R.I. breeding programme in effect outdated the Nigerian one.

It is thought that materials and results from both schemes should be incorporated in a specifically Nigerian breeding programme and therefore a reassessment of both is under way. As a first step to such a closely adapted breeding scheme a clear appreciation of the local problems of cocoa culture was necessary. For the main producing area these are:

1. Establishment, owing to the severe dry season in the Western Region.
2. Black-pod and swollen shoot diseases.

The preliminary objects of the breeding programme will be directed into solving these problems, in close co-operation with other research work on these lines. It is thought that the main reasons for low yields are bad establishment, losses by diseases and a very low level of maintenance. It should be remembered that yields of 800-1,000 lb. dry cocoa per acre were considered normal in the 1930's whereas today 300 lb. is considered to be the mean. Only after an economic solution has been found to the above mentioned problems will breeding specifically for higher yields receive main attention. However, work on the immediate breeding scheme will be carried out on cocoa material of known good performance, early bearing and quality.

*T38 will from now on be called N38 following Posnette's nomenclature to avoid confusion with W.A.C.R.I. Trinidad introductions of 1944.

In addition, more academic research work to obtain stocks with special characteristics such as very high levels of disease tolerance, disregarding quality and to a certain extent yield, will be carried out. This work may be speeded up considerably by the use of such techniques as the mechanical transmission of virus and the early assessment of black-pod tolerance by the infection of root systems with *Phytophthora palmivora*. Both of these are at present being actively developed.

The mature cocoa material at Gambari consists of part of the 1944 Trinidad introductions, local selections, ICS clones, some white seeded material from the Cameroons, the W.A.C.R.I. C-clones, and a few miscellaneous introductions from Ceylon and Samoa. Furthermore, the so-called F₂ open pollinated Amazon seed orchards are considered as of high importance in relation to selection for disease tolerance and yield. These stocks or gene pools will form the nucleus on which the long term breeding programme will be based.

INTRODUCTIONS (H. Toxopeus)

It must be borne in mind that the so-called F₀ parents, from which the F₁ and to a large extent the F₂ and F₃ Amazon populations descend are Na31, 32, 33, 34, Pa7, 35, Sca12, IMC24, 53, 47, 60 and 3 unknown parents, making 14 in all. This is a narrow genetical basis from which to breed, especially for a crop of which the individual trees stand in the field for a considerable number of years under a low standard of cultivation, with all the possibilities of disease adaptation. Additional new introductions therefore seem necessary to broaden this basis, and it would be logical to follow up the last large scale introduction in 1944, into West Africa. This introduction, which was on the broadest possible genetical basis, gave definite indications as to where the badly needed tolerance source for swollen shoot might be sought. Different populations (Sca; Na; Iquitos) from the Amazon headwaters show such tolerance and much more besides. Pound succeeded in transferring much material to Trinidad where 32 plants were raised from clonal introductions and 2,500 from seed. That collection forms the most promising source from which further material might be introduced to West Africa and action along these lines is being taken.

This year large scale seed introductions were made from Tafo for planting out in field trials in Nigeria. From Trinidad budwood of Sca6 and 9, Pa34, IMC76 and 47 was received along with some clonal introductions from Tafo. Contacts with IFCC and ACRI were laid down with the idea of co-operation in exchange of material.

In connection with the virus tolerance work, a programme of selfing genotypes with incompatibility alleles was carried out, using the technique described by Glendinning (Glendinning, D. R., *Nature, Lond.* **187**, 4732, 170, 1960). This technique involves using pollen on the self-incompatible clone together with 'starter' pollen from a clone compatible with it. The compatible clone used here, C24, is homozygous for the dominant alleles governing 'axil-spot' (Harland, S.C., and Frenchville, G. E., *Genetic*, 9, (4-6), 279, 1927. Voelcker, O. J., *Ann. Rep. Cocoa Res. I.C.T.A.*, **7**, 9 (1937), 1938), which character was used as a marker gene.

Four self-incompatible W.A.C.R.I. 'C' clones were selfed in this way and in the progenies some seedlings showed 'axil-spot' and others did not. The former are believed to be hybrids between C24 and the incompatible clone and the seedlings without 'axil-spot' are believed to be selfs. The numbers of hybrids and selfs in the four progenies are shown in Table 66.

TABLE 66

The numbers of hybrids (C24 × Amazon clone) and selfs in the progenies of four selfed W.A.C.R.I. clones

Parentage	(a) 'Axil-spot' seedlings (hybrids)	Selfed seedlings	Ratio a : b	Selfs as % of total progeny	Incompati- bility alleles*
1. C64 (Na 32)	1828	473	3.9:1	21	2 & 4
2. C77 (T85/799)	432	28	15.4:1	6	4 & ?
3. C70 (T12/113)	516	35	14.7:1	6	0 & 3
4. C76 (T86/982)	220	54	4.1:1	20	5 & 6

* As determined by Rogers and Knight (unpublished data)

From these ratios it is clear that crosses 1 and 4, and 2 and 3 are quite different. The possibility that this difference is related to their incompatibility alleles is being examined and further investigations may assist in determining the dominance relationships of the S alleles.

Many beans had a distinct red/purple circle on the tip of the radicle and this was more obvious when the testa was removed. This character does not appear to have been described and is termed here 'purple-eye'. The segregation of 'purple-eye' in the hybrids is shown in Table 67.

These results indicate a segregation ratio of 1:1. There was a wide range of intensity of pigment in the 'purple-eye', from a deep purple

TABLE 67

Segregation of 'purple-eye' in the hybrids between the compatible and incompatible clones

C24	No. of beans	(a) 'Purple-eye' beans	(b) Beans without 'purple-eye'	Ratio a : b
1. C64	1,828	1,050	778	1.3 : 1
2. C77	432	274	158	1.7 : 1
3. C70	516	218	298	1.1 : 4
4. C76	220	97	123	1.1 : 3
Total	2,996	1,639	1,357	1.2 : 1

to a very faint red colour which was often only detectable with a hand lens and this difficult distinction may have affected the segregation ratio in a systematic way. Another complicating factor was that some of the selfed progeny showed 'purple-eye', though in most cases this was very faint. This suggests that the Amazon parents may have factors for this character and that these factors may be minor genes, which could interact to some extent with the segregation of the major gene.

The ratios in the hybrids indicate a monofactorial inheritance of 'purple-eye', with 'purple-eye' (Pe) dominant with minor gene interaction. Hence C24 would be of the genotype *Pepe* and the Amazon clones *pepe*. Further conclusions about this genetic system await the completion of a new series of pollinations.

SOIL CHEMISTRY

(M. Wessel)

FERTILIZER TRIALS

A fertilizer trial has been laid down at Araromi farm about 25 miles south-east of Ibadan. The eight treatments are NP., KMg., and NPKMg., all at two levels, mulch and no fertilizer and bare soil and no fertilizer as control. There are six replications and 30 experimental trees per plot.

Amazon seedlings were planted at the beginning of June at a spacing of 4 feet by 4 feet, under existing banana shade planted at 12 feet by 12 feet. The fertilizer rates at level 1 are 50 gm. urea, 30 gm. triple superphosphate, 40 gm. potassium sulphate and 40 gm. magnesium sulphate per tree; those at level 2 being twice as high.

One half of the fertilizer was applied in June and the other half in September. During the dry season plants were watered twice weekly. Girth records were taken in November and February.

The present data indicate big differences in growth only between mulched and bare-soil plots.

ZINC DEFICIENCY

Zinc deficiency in young seedlings

The occurrence of zinc deficiency in the Gambari nursery was reported in W.A.C.R.I. Quarterly Progress Report 62. Since Gambari soil is used in the W.A.C.R.I. greenhouse on Moor Plantation, occurrence of zinc and iron deficiency, separately or in combination with each other, is not uncommon. Although this can be corrected by spraying with zinc and iron solutions, a better approach to the problem would be to find a soil in which cocoa seedlings can be grown without the present implications. For this purpose topsoil has been collected from four different sites (referred to here as A, B, C, and D) at the Gambari Station. Using these samples, pots were filled and each soil given the following four treatments:

Treatment 1: Nil.

Treatment 2: 1.5 gm. Ca. (to induce zinc deficiency by raising the pH of the soil).

Treatment 3: 30 mgm. Fe and 30 mgm. Zn.

Treatment 4: 30 mgm. Fe and 30 mgm. Zn. and in addition N, S, P, Ca, K and Mg.

The N, S, P, Ca, K and Mg. in treatment 4 were given in solution at fortnightly intervals; all other treatments were applied to the soil before Amelonado seeds, one per pot, were planted on 17/8/61. After five months the plants were harvested and the total number of leaves, the number of leaves with zinc deficiency symptoms, stem length and fresh weight of the aerial parts estimated. In Table 68 below some chemical data for the soil and the percentages of zinc deficient leaves under the various treatments applied to each soil are given. Soil pH was estimated in water suspension, carbon by the method of Walkley and Black, available P by NH_4F extraction, and exchangeable K by NH_4 -acetate extraction.

TABLE 68

Zinc deficiency in relation to several chemical factors

Soil	pH	% C	% Total N	Available P (ppm.)	M.e. K/ 100 gm. soil	% deficient leaves per plant in treatments ⁽¹⁾			
						1	2	3	4
A	7.8	4.2	0.42	165	0.35	23	24	8	7
B	7.5	3.2	0.31	34	0.38	9	24	1.4	2
C	7.4	2.3	0.19	15	0.39	7.4	6.6	5	—
D	7.0	1.6	0.17	10	0.28	—	—	—	—

⁽¹⁾ The figures are averages of 9 plants.

The table shows that high pH and high levels of carbon and phosphorus are associated with a high percentage of zinc deficient leaves. Liming the soil (treatment 2) increased the number of zinc deficient leaves on soil B. The addition of zinc and iron (treatment 3) considerably reduced the occurrence of zinc deficiency on the first three soils. On soils A and B zinc and iron together gave a growth-increase of 10 and 20 per cent respectively, while the additional NSPCaKMg. gave a further growth increase of about 10 per cent. Plants on soil C responded only to treatment 4. Soil D differed from the others not only because there were no deficiency symptoms in any treatment, but also because there was a clear negative response to treatments 3 and 4.

The results of this experiment make it clear that from the point of view of deficiencies, D is the most desirable of the four soils tested. However, because of its rather low nutrient status it was decided to use a mixture of soils C and D in the nursery and greenhouse. The soils and plants of this experiment were sampled for a future Zn analysis.

In the experiment discussed, it was observed that zinc deficient seedlings initially produced 1-2 normal flushes, followed by 1-3 flushes with distorted leaves and afterwards formed normal foliage. The fact has also been reported by others (Greenwood, M. and Hayfron, A. J., *Emp. J. Exp. Agric.*, **19**, 71-86, 1951), but no explanation can be given yet. The study of zinc deficiency is being continued.

Zinc deficiency in two-year-old seedlings

In January, 1962, severe symptoms of zinc deficiency were observed in two-year-old Amazon cocoa at Idi-Ose. This cocoa, which was planted in 1950 in two large blocks of 726 trees spaced at 5 feet by 5 feet, is part of a Western Region Ministry of Agriculture and Natural Resources establishment trial. Both blocks were mulched with grass and had inert overhead shade of palm leaves supported by bamboo during the 1960-61 dry season. At the time of planting 1½ oz. of an NP compound were applied in the planting holes in one block, and 3 oz. in another block. Establishment was excellent and by October, 1961 the losses on both plots were less than 1 per cent, and the canopy was almost closed.

When the plots were inspected at the end of January, severe zinc deficiency symptoms were found on many trees in both plots. The deficient trees were classified in four groups according to the percentage of foliage showing deficiency symptoms and the data for both plots together are summarized in Table 69.

Although affected trees were found all over the plots, it was possible to select twelve square plots each of nine trees, six plots with

TABLE 69
Zinc deficiency at Idi-Ose

Percentage foliage deficient	0	1-25%	25-50%	50-75%	75-100%	Leafless	Dead
% trees in foliage deficiency categories	51%	23%	10%	4%	2%	6%	4%

deficient and six with symptomless trees. Soil samples were taken and pH and available P determined. The pH values varied between 6.5 and 7.2 and P figures between 18 and 40 ppm. There was no suggestion that the highest figures were associated with 'deficient' plots. At the end of March, when all trees were flushing heavily, a new inspection was carried out on the twelve selected plots. On the originally symptomless plots 48 per cent of the trees now had symptoms of zinc deficiency and most of the trees in the establishment trial were showing symptoms of iron deficiency. As soon as zinc determinations can be made it will be possible to determine whether the deficiencies, are associated with low Zn and Fe levels in the soil, or are induced by adverse growing conditions such as high pH, high levels of potassium and phosphorus, drought and insufficient shade, as reported by Loué (Loué, A. (1961) *Etude des carences et des deficiencies minerales sur le cacaoyer. I.F.C.C. Bull. No. 1, 38-40*), and Schroo (Schroo, H. (1959) *Acute zinc deficiency observed in cocoa on certain soil types in Netherlands New Guinea. Neth. J. Agric. Sc., 7, 309-317*).

In conjunction with the Western Region Department of Agriculture an experiment will be conducted at Idi-Ose to find out the most effective therapy.

AGRONOMY

SPACING TRIAL (G. H. Freeman)

The yield from the Amelonado spacing trial at Gambari is shown in Table 70.

The results are given both as pounds of dry cocoa per acre and as pods per tree. The pods per tree are known exactly, since the trial is being used also as a black-pod control trial, and the figures for weight of dry cocoa have been derived on the assumption that twelve pods give one pound of dry cocoa. It will be seen that, compared with the 1960-61 crop (*Rep. W. Afr. Cocoa Res. Inst., 1960-61, p. 93*),

TABLE 70
Yield in 1961-62 from the Amelonado spacing trial planted in 1942 at Gambari

Spacing (feet)	15' × 15'	12' × 12'	10' × 10'	7½' × 7½'	6' × 7½'	6' × 6'	5' × 5'
Dry cocoa per acre (lbs.)	587	765	766	1199	980	1263	1384
Pods per tree	36.4	30.3	21.1	18.6	12.2	12.5	9.5

there has been a decrease in yield at the closer spacings but not at the wider spacings. Nevertheless, the closer spacings continue to yield much more heavily when crop per unit area is considered.

NURSERY TRIAL (G. H. Freeman)

The main trial conducted in the nursery during the 1960-61 season has already been described (*Rep. W. Afr. Cocoa Res. Inst.* 1960-61, p. 92). Four trees from each plot were sampled in June, 1961 and the remainder planted out in the field at a spacing of 5 feet by 5 feet on clear felled land. The area was kept free from weeds, and an inert shade of palm fronds on bamboo was erected in November at the start of the dry season. Observations have continued, and Table 71 shows the trunk girth, recorded at six inches above the ground, at the time of planting and in March, 1962.

It will be seen that the pattern is not quite the same at the two times, although in general the trees biggest in June, 1961 remained the biggest in March, 1962. The principal exception is that the trees derived from beans sown in the nursery in February, 1961, under heavy shade with watering only twice a week have grown particularly well in the field and are now bigger than any from the two previous sowing dates. This result was quite unexpected at the time of transplanting and emphasizes the importance of continuing nursery trials until the trees have been at least one year in the field. Further, trees derived from beans sown in January, 1961, at the height of the harmattan, with no shade, have done even worse than expected.

The records of numbers of trees dead and of trees jorquetted in March, 1962, shown in Table 72 confirm the trends shown by the girth records at the time.

Trees started to die during a six weeks' dry spell in August and September, 1961, and deaths continued thereafter, though not especially rapidly during the main 1961-62 dry season. The death rate was very high in trees derived from beans sown without shade in January or February, 1961; for all other treatments it was much lower and probably unimportant in practice, and gives confidence in the methods employed in the nursery and, so far as can be judged to date, in the field. Plants from the earliest sowings were jorquetting within ten months from the bean. Many of the jorquettes are less than three feet from the ground, and this may cause problems in the future.

Another trial has been started to follow up the results of the 1960-61 nursery trial. In this trial times of sowing and of transplanting to the field are both being varied. Beans were sown in the nursery in October, November and December, 1961, under a shade slightly

TABLE 71
Girth in cm. per tree in the field in June 1961, and March 1962, for the 1960-61 nursery trial

Time of sowing	June, 1961			March, 1962		
	No shade	Light shade	Heavy shade	No shade	Light shade	Heavy shade
	Infrequent watering	Frequent watering	Infrequent watering	Infrequent watering	Frequent watering	Infrequent watering
November 1960	0.50	0.74	0.88	0.81	1.75	1.59
December 1960	0.46	0.59	0.71	1.04	1.28	1.38
January 1961	0.27	0.28	0.53	0.37	1.19	0.95
February 1961	0.23	0.26	0.41	0.81	0.85	1.03
5% significant difference			0.126			0.414

The shade and watering treatments were applied in the nursery only, all trees being treated in the same way in the field

TABLE 72

Percentage of trees dead and of trees jorquetted in the field in March 1962 for the 1960-61 nursery trial

Time of sowing	Percentage of dead trees				Percentage of jorquetted trees			
	No shade		Heavy shade		No shade		Light shade	
	Infrequent watering	Frequent watering	Infrequent watering	Frequent watering	Infrequent watering	Frequent watering	Infrequent watering	Frequent watering
November 1960	11	6	0	5	54	73	65	55
December 1960	18	8	5	4	34	41	44	39
January 1961	59	61	11	8	3	0	39	25
February 1961	29	35	11	13	13	3	13	23
5% significant difference								
				13.6				25.9

The shade and watering treatments were applied in the nursery only, all trees being treated the same way in the field

heavier than the light shade of the 1960-61 trial, and the plants watered twice a week. The same arrangement of plants within a plot was adopted as for the 1960-61 trial and there were four replicates of each combination of sowing and transplanting dates. Since the earlier trial had shown no differences between polythene and 'whalehide' pots, all the beans were sown in the lighter and cheaper polythene pots. The cocoa is F3 Amazon, from open-pollinated T60 and T79, reciprocal crosses. Trees from each of the three times of sowing will be planted out in the field in each of May, June and July, thus giving trees from five to nine months old at the time of transplanting. Seed will also be sown at stake at the three times of planting in the field.

There was rather poor germination of T79 in November, due to the unavoidable use of some small beans; germination was quicker in October than either November or December, harmattan conditions being experienced at both the later times. Some zinc deficiency symptoms were observed, but these disappeared after the trial had been watered several times with a sulphate of ammonia solution to lower the pH of the soil. Records of leaf number and height in March, 1962 show the expected differences between plants of different ages, but no consistent differences between T60 and T79. In this trial it will be the establishment period that is most important.

SHADE OBSERVATION TRIAL (G. H. Freeman and M. Wessel)

A trial to observe the effects of various shade treatments on the growth of cocoa was started in 1961. Cocoa was planted in June, as were four shade crops: tree cassava, plantain, pigeon pea (*Cajanus cajan*) and sunn hemp (*Crotalaria juncea*). All the shade crops established reasonably well, except for the plot of plantain, but the *Crotalaria* was so badly damaged by a storm that it had to be abandoned. Two forms of inert shade were also tried, viz., a palm frond tripod and a plastic mulch on the soil. The tripod was erected in June, and the plastic was laid on the ground, between the rows of cocoa, either then or in October. The ground was clean-weeded in all treatments and there was also a treatment consisting of clean-weeding only, with no cover for the cocoa or the soil. There were only two replicates of 100 trees each, the cocoa being mixed Amazon planted at 5 feet by 5 feet, as the main purpose of the trial was to give preliminary information for use in planning a larger trial to be planted in 1962.

Table 73 shows the soil moisture percentage just before the first rain of 1962, the percentage of dead and leafless trees and the height per tree one month later.

TABLE 73

Records taken at the end of the 1961-62 dry season on the shade observation trial

	<i>Plastic mulch</i>	<i>Palm frond tripod</i>	<i>Bare soil</i>	<i>Living shade</i>
<i>Soil moisture percentage</i>	11.3	7.0	4.0	3.6
<i>Percentage of dead or leafless trees</i>	28.0	2.5	26.5	64.2
<i>Mean height per tree in inches</i>	34.9	48.7	30.5	30.5

The two plastic mulch treatments gave similar results, as did the three living shades, tree cassava, plantain and pigeon pea; the *Crotalaria* treatment was not considered. The best growth was with the palm frond tripod even though the soil was drier than under the plastic mulch. Next in growth came cocoa with the plastic mulch, that with the bare soil being only slightly worse though the soil was very much drier. The living shade treatments had soil of about the same moisture and trees of the same height as the bare soil, but far more trees either dead or leafless.

STATISTICS

(G. H. Freeman)

Design and analysis of experiments has continued, both for W.A.C.R.I. and in collaboration with other organisations, both government and commercial. Studies of the relations between trunk girth and yield of cocoa trees have led to a paper submitted for publication by J. F. Longworth and G. H. Freeman. The various records that are taken on young cocoa trees are being examined with a view to making recommendations for the better recording of trials in their early years.

On the Amelonado spacing trial at Gambari a trial on the control of black-pod by fungicides was carried out in 1961 and another has been planned for 1962. These gave rise to some difficulties, as the design of the spacing trial was a 7×7 Latin square with no Graeco-Latin solution; that is, it was impossible to add a further set of seven treatments orthogonally so that each occurred once on each row, column and spacing of the original trial. In 1961, seven fungicide treatments were used, each of which was replicated six times, being omitted on one row, column and spacing, while an unsprayed control was replicated seven times, occurring on every row, column and spacing. For 1962 the 1961 black-pod treatments have been ignored and a similar trial with six replicates and seven fungicides and seven of control laid out, the whole design being re-randomised. Designs of this type would be useful for other trials where treatments need to be added to a Latin square with no Graeco-Latin solution. There is never such a solution for a 6×6 Latin square, and an unfortunate choice of the original Latin square might lead to an insoluble situation for any number of treatments. Methods of analysis and appropriate experimental designs are being studied for the general case, particular attention being paid to the 6×6 and 7×7 squares.

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BALANCE SHEET
AS AT 31st MARCH, 1962

LIABILITIES

	£G	s.	d.
BALANCE OF ENDOWMENT as at 1st April 1961	1,933,363	5	8
Less Excess of Expenditure over Income for the year ended 31st March 1962, as per Income and Expenditure Account, Schedule I	475,637	3	2

(Sgd.) R. G. DONALD, *Officer-in-Charge.*(Sgd.) J. N. A. HYDE, *Accountant.*

BALANCE OF ENDOWMENT as at 31st March 1962, carried forward £G1,457,726 2 6

Notes: The balance of £G11,522 3s. 1d. due from the Division of Public Construction in con-
provision has been made in the Accounts dated 31st March, 1962 for £G14,401 1s. od. for
£G23,928 14s. 7d. at Ibadan. Expenditure on Land and Buildings and Furniture and
follows:

Cost to 31st March 1961	..	..	..
Additions during year	..	..	..

Less Amounts written off	..	..	..
--------------------------------	----	----	----

We have audited the above Balance Sheet of the West African Cocoa Research Institute
explanations that we have required. In our opinion this Balance Sheet sets forth a true and
the best of our information and the explanations given to us, and as shown by the books of

ACCRA,

13TH OCTOBER 1962.

T 31st MARCH 1962

ASSETS

	£G	s.	d.	£G	s.	d.
<i>Represented by:—</i>						
INVESTMENTS—OVERSEAS—At Cost				1,966,861	17	7
(Market Values at 31.3.62 £G1,610,592 11s. 4d.)						
Less Advances from Joint Miscellaneous Fund				519,000	0	0
				<u>1,447,861</u>	<u>17</u>	<u>7</u>
INVESTMENTS—LOCAL—At Cost						
Government of Ghana 5% Registered Stock—						
1965/66	5,000	0	0			
Ghana National Development Bonds	581	14	0			
				<u>5,581</u>	<u>14</u>	<u>0</u>
				<u>1,453,443</u>	<u>11</u>	<u>7</u>
CURRENT ASSETS	£G	s.	d.			
STORES—At Cost						
Maintenance	12,657	9	3			
Timber	3,094	3	4			
Fuel	766	19	7			
Films	164	5	4			
				<u>16,682</u>	<u>17</u>	<u>6</u>
SUNDRY DEBTORS—						
Staff Advances—Tafo	15,561	12	2			
Ibadan	5,591	11	1			
Miscellaneous Debtors	3,322	19	10			
Deposits and Prepayments	13,511	16	4			
				<u>37,987</u>	<u>19</u>	<u>5</u>
CASH IN HAND, AT BANK, AND WITH CROWN AGENTS				<u>37,159</u>	<u>16</u>	<u>7</u>
				<u>91,830</u>	<u>13</u>	<u>6</u>
DEDUCT: CURRENT LIABILITIES						
Sundry Creditors	20,904	12	9			
Provisions and Accrued Charges	66,133	18	0			
Tender Deposit Refundable	2	15	3			
Contract Penalties—						
carried forward	400	0	0			
Departmental Charges on Stores						
—carried forward	106	16	7			
				<u>87,548</u>	<u>2</u>	<u>7</u>
				<u>4,282</u>	<u>10</u>	<u>11</u>
				<u>£G1,457,726</u>	<u>2</u>	<u>6</u>

nection with the renovations to the W.A.C.R.I. Village has been carried forward, and 16 years rent of the Tafo lands, and for uncompleted works — £G14,935 9s. 8d. at Tafo, and Equipment for the year ended 31st March, 1962, has been written off in the Accounts as

<i>Land and Buildings</i>	<i>Furniture and Equipment</i>
508,473 16 2	88,486 19 9
170,547 8 5	13,622 1 4
679,021 4 7	102,109 1 1
£G679,021 4 7	£G102,109 1 1

with the books and vouchers of the Institute and have obtained all the information and correct view of the financial position of the Institute as at the 31st March 1962, according to the Institute.

(Sgd.) CASSLETON ELLIOT,
Chartered Accountants.

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